Vol. XXI. — No. 4. April 1939.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[656. 2]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION.

INQUIRY INTO QUESTIONS OF GENERAL INTEREST.

(Decision taken by the Permanent Commission at its Meeting held on July 19th, 1938.)

QUESTION II.

How should the problems of simplifying the working be considered, in the future, in the interest both of the public and of the railways?

REPORT

(English speaking Countries and Belgium)

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To make the scope of the question quite clear and explain the spirit in which the detailed questionnaire relating to it was drawn up, the following foreword was added :

« During its 1937 (Paris) Session, the International Railway Congress Association studied « the economical operation of the main-line systems' secondary lines » (Third Section — Question VII of the Agenda).

« The Permanent Commission of the Association thought that in view of the frequent deficits of Railway Administrations, it would be advisable to keep these Administrations informed about the evolution of this question, and in particular about the results obtained and the new methods introduced or suggested since the last Session of the Congress.

« The Commission also thought it advisable not to limit the investigations to the simplification of the working of the secondary lines, but also cover both the important and average lines, which form the essential part of the main-line systems.

« This latter question is undoubtedly more complex than the former.

« The volume of traffic on the main lines requires expensive equipment and a large staff which it is difficult to adapt to variations in the traffic.

« On the other hand though the legal obligations of the Railway Administrations as regards the transport of passengers and goods have been mitigated in the case of secondary lines, they have remained practically unaltered on the important and average lines where they are undoubtedly of greater interest for the public.

« The questionnaire is consequently divided in two parts :

« — the first part, dealing with the simplified working of *main lines,* has as its object not only to collect as complete a documentation as possible on what has already been done in this connection, but also to co-ordinate the ideas and suggestions which may be put forward;

« — the second part, dealing with the economical operation of *secondary lines,* is merely intended to complete the information already collected about this subject in 1937. »

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The detailed questionnaire was sent to 49 Railway Administrations and Companies belonging to the International Railway Congress Association; 18 of them sent in a reply. Eight said that the way in which their system was operated did not enable them to supply any useful information, these being the :

- Bessemer and Lake Erie R.R.;
- Compagnie des Chemins de fer du Congo Supérieur aux grands lacs africains (Belgian Congo);
- Ferro Carril Central Argentino;
- Great Northern Railway (Northern Ireland);
- Kenya and Uganda Railways and Harbours;
- New Zealand Government Railways;
- Nigerian Railways;
- Sudan Railways.

The *County Donegal Railways* and the *London Passenger Transport Board,* not being greatly interested in this problem, only sent in summary information.

Only eight Companies replied at any length, these being :

- *Belgium and Colony :* The Belgian National Railways Company;
- *Egypt :* State Railways;
- *United States of America :* The Baltimore & Ohio Railroad;
  The Pennsylvania Railroad;
- *Great Britain and Northern Ireland :* The Railway Clearing House (on behalf of the British Railway Companies);
- *British India, Dominions, Protectorates and Colonies :* Bombay, Baroda & Central India Railway;
  H.E.H. The Nizam's State Railway.
- *Eire :* Great Southern Railways.

Their replies are summed up below.

A. — General.

QUESTION I. — *On what characteristics (kind of traffic, speed, financial balance sheet, etc.) can the classification of the lines be based, the object of such a classification being to group the lines in one or other of the following categories :*

(1) *important and average lines on which in principle the standard methods of working are followed;*

(2) *secondary lines with simplified working ?*

Answers.

The replies received indicate that up to the present there is no general rule for fixing the characteristics of the important lines and the secondary lines. In this connection each administration has its own criterion.

Generally speaking, the classification is based on questions of speed and tonnage, without taking the financial operating results into account.

On the *Belgian National Railways Co.* the classification of the lines is determined by the speeds authorised and the daily tonnage carried.

Important lines are taken to be those on which the tonnage is more than 10 000 tons and the authorised speed equal to or more than 90 km. (56 miles) an hour.

If one or other of these conditions is

not fulfilled the line is at once classified as a secondary line.

Statistics of receipts and expenditure show profits and losses in each class.

On the *Pennsylvania Railroad* and the *Baltimore and Ohio Railroad,* lines over which high-speed through passenger trains and heavy long-distance goods trains are worked are classified as *important* or *average* lines.

On the *British Railways,* in practice there is no classification. The term « secondary line » is not used; it might however be applied to some of the branch or cross-country lines where there is little traffic and the speed is low. It is on lines such as these that simplified operating methods have been adopted or are under consideration.

On the *Bombay, Baroda and Central India Railway,* lines over which through passenger and goods trains are worked at a speed of 60 miles an hour are called « important lines ».

The « secondary lines » are those where the speed is only 20 to 40 miles an hour. These lines act as feeders for the main lines.

On the *Nizam's State Railway* there are *important standard-gauge lines* over which more than 3 million gross ton-miles per mile are carried annually, and *important narrow-gauge lines* where the traffic is about 2 million gross ton-miles annually.

The *secondary lines* are those where the traffic is not so great.

On the *Great Southern Railways* lines are classified as *important* or *secondary* according to the intensity of the traffic and the axle loads allowed.

QUESTION II. — *What is the extent of each category of lines in relation to the whole system?*

What is the proportion of the receipts, costs and working results allocated to each category?

Answers.

Generally speaking, the railways replied that they do not get out separate balance sheets showing the receipts, expenditure, and operating results for each class of line.

The *Belgian National Railways Company* has drawn up approximate balance sheets for each line based on the accounts for two months. These balance sheets have been used to divide the lines into those showing a loss and those showing a profit.

The *Bombay, Baroda and Central India Railway* keeps separate accounts for each class of line. The figures for the main lines are :

Gross receipts : 12.52.10.900 Rupees.
Gross expenditure : 6.86.69.900 Rupees.
Nett receipts : 5.65.41.000 Rupees.

On the secondary lines, the receipts per line vary from 1.009.500 to 11.000 Rupees.

The following table shows the extent of each category of lines in comparison with the total mileage of the system :

Railway.	Main lines, % of total.	Secondary lines, % of total.	Aggregate length of system. (route-miles)	Remarks.
Belgian National Railways Company	55.5	44.5	3 012	...
Baltimore and Ohio Railroad	65	35	6 158	...
Pennsylvania Railroad	27	73	10 207	77 % of the traffic is carried by the main lines.
Bombay, Baroda and Central India Ry.	89	11	3 937	...
The Nizam's State Ry.	79	21	1 348	...
Great Southern Rys. (Eire)	62	38	1 987	...

QUESTION III. — *To what extent have the proposed simplifications in the working to be approved by the public authorities ?*

What are the principal legislative enactments in force or under consideration in this connection ?

Answers.

On most railways, only those simplifications in the working which affect the safety or convenience of the public have to be submitted for approval by the Authorities.

In the case of the *Belgian National Railways Company,* the approval of the Minister of Transport has to be obtained :

(a) for the abandonment of a railway line whether or not its place is taken by an omnibus service;

(b) for converting a double-track line into single track;

(c) for the introduction of simplified working, including in particular doing away with keepers at level crossings.

The object of having such measures sanctioned by the Minister is to safeguard the national interests and national defence.

The laws on the general working of the Railways contain no well defined regulations on the subject of simplified working.

The *British Railways* report that no authorisation is necessary in order to close down a station or turn it into a non-staffed halt, unless a special law or agreement prevents this.

The principal legal regulations in force dealing with railway operation are codified in the « Requirements for Passenger Lines and Recommendations for Goods Lines of the Minister of Transport in regard to Railway Construction and Operation ».

The *Baltimore and Ohio Railroad,* the *Pennsylvania Railroad,* the *Bombay, Baroda and Central India Railway* all replied that the authorities have to approve any change or simplification in the working (giving up lines, closing down stations, suppressing trains) and that the laws or various State decrees dealing with public services cover the working of the railways.

QUESTION IV. — *Is the obligation to carry all kinds of persons and goods from any station to any station an obstacle in the way of simplification, and if so, to what extent ?*

Answers.

Generally speaking the replies received were in the negative.

The *Belgian National Railways Company,* the *Pennsylvania Railroad* and the *Nizam's State Railway* pointed out that certain costs could be avoided if such an obligation did not exist, for example those due to working trains which run at a loss.

B. — Simplification of the working of important and average lines.

QUESTION V. — *On the important and average lines, are all stations on the system (large and small stations, halts, etc.) given train services, both passenger and goods, or are only the large centres served by rail ?*

Answers.

The railways replied unanimously that there are services to all the stations. In certain cases, however, there are only goods trains and in others only passenger trains (stations turned into halts). The volume of traffic consigned or received determines the number and schedules of the trains serving the stations.

In the case of halts closed for goods traffic, the sidings are no longer maintained; if there is no staff, tickets are issued on the trains (in *Belgium* and *Egypt*).

QUESTION VI. — *When the railway services are limited to the large centres, how are other places served ?*

Answers.

This case does not arise on any of the railways replying to the questionnaire (see reply to Question V).

QUESTION VII. — *When all the traffic is worked by rail, how are small centres served, as regards both passenger and goods services (full-wagon loads and small consignments) ?*

Answers.

The railways are endeavouring to reduce the cost by using light locotractors in the case of goods traffic and railcars in the case of passenger traffic. Generally the small stations are open only part of the day.

On the *Belgian National Railways Co.*, in particular, in order to reduce the working hours at small stations, the booking office is only open for a few hours every day; at other times tickets are issued and collected in the trains.

In the same way, goods can only be accepted and transport charges collected during part of the day.

The goods yard remains open while the pay-office is closed.

On this railway and on the *British Railways,* small consignments from concentration stations for one or several small successive stations are grouped together in a single wagon and unloaded onto the platforms.

The reverse process is resorted to in connection with small consignments handed in at these small stations. Small parcels can also be sent by passenger train if there is any advantage in this.

On the *Bombay, Baroda and Central India Railway* goods collected from intermediate stations are sorted in the tranship (parcels) trains by the loaders.

Goods to and from places at some distance from the railway are sometimes worked by road. In *Belgium* road transport is preferred to railway transport for parcels traffic in the case of lines with heavy traffic, in order to reduce the number of trains.

QUESTION VIII. — *What simplifications of the working have you already introduced, or do you propose to introduce as regards :*

(1) *the fixed plant (track, buildings, signals, etc.);*

(2) *the station staff;*

(3) *the train staff (enginemen, guards, etc.) ?*

Answers.

1. The following measures enable savings to be made in the cost of maintenance, renewal, first cost, and working of fixed plant :

— standardisation of the station equipment, particularly in the case of intermediate stations, and limiting the safety equipment to correspond with the needs of the service and the speed of the trains;

— total or temporary suppression of intermediate blocks;

— suppression of signals that are not strictly necessary;

— taking out of service those tracks no longer required to work the traffic;

— concentration of signalmen's and pointsmen's duties;

— simplification of the maintenance (chemical weeding, removal of hedges; mechanisation);

— dispensing with keepers at certain level crossings, after making the necessary safety provisions (see *Question XIV);*

— rational use of premises and demolition of useless buildings;

2. The station (non-travelling) staff can be reduced by :

(a) Scientific organisation of the work;

(b) Simplification of the clerical work, especially at intermediate stations, the accounts being kept at one managing station;

(c) Reduction of the time during which lines and stations are open;

(d) Charging the train staff with certain preliminary work formerly carried out by the station staff, such as :

— coupling up and uncoupling the locomotive, testing the brakes before departure, turning locomotives on the turntables;

(e) Combining the duties of the staff, especially at intermediate stations. Certain examples of this are given hereafter :

The station master is in charge of the passenger and goods services and of the accounts; in the case of the first and last trains, the tickets are issued by an underling (workman) or by the train staff; the ticket collectors at station exits help in the handling of parcels; the clerical staff work the point and signal operating equipment fitted in the booking office for this purpose.

Other possible ways of simplification are mentioned under *Question XII.*

3. Measures enabling the enginemen and train staff to be reduced are mentioned in *Questions XIII and XX.*

The railways are decreasing the staff employed on the trains by reducing the mileage of the trains to the utmost minimum.

The *British Railways* have reduced the number of inspectors employed on the trains by increasing the control at the entrance and exit of the large stations.

QUESTION IX. — *In the case of fixed plant, are the simplifications introduced at all stations ? Are they limited to the intermediate stations, the large centres being excluded ?*

What happens to the intermediate stations when they are no longer served by rail ?

Answers.

As a rule simplified working is not confined to the intermediate stations, but is general whenever it is possible to make it so without inconveniencing the public or the railway service. The *Belgian National Railways Co.*, for example, are systematically revising all the fixed plant in order to keep it within the strictly necessary limits, thereby reducing the cost of service, maintenance and renewal. Equipment that is not used is recovered in this way and taken advantage of to improve the plant maintained in service.

Railways which have closed down any stations generally continue to serve the localities concerned by means of motorbus and motor lorry services.

It does not appear that the organisation of such services obliges the railways to keep open the offices of closed down stations.

In certain cases the railways have not introduced any other transport services to take the place of those suppressed and are trying to let the buildings in closed down stations.

QUESTION X. — *Does the automatic block equipment of the main lines, which augments the capacity of the lines and greatly increases the safety, show any real savings as compared with manually-operated signals ?*

Answers.

Only the *Baltimore and Ohio Railroad*, the *Pennsylvania Railroad* and the *London Passenger Transport Board* use the automatic block, and they have answered in the affirmative.

The *British Railways* consider that in every case the balance sheet should take into account the expenditure and savings on staff; on the *Belgian National Railways Co.* there is no automatic block, as it would not give any appreciable saving because the stations are too near together.

QUESTION XI. — *In the case of important single-track lines, do such methods as centralised traffic control (C. T. C.) give a saving in comparison with doubling the track, whilst giving sufficient flexibility and adequate capacity ?*

Answers.

The *Pennsylvania Railroad,* the *Baltimore and Ohio Railroad* and the *Nizam's State Railway,* which alone make use of this method, replied in the affirmative. The other railways have no information available. The *Belgian National Railways Co.* states that it does not intend to make use of centralised traffic control, owing to its complication and high first cost.

QUESTION XII. — *How can the station staff be reduced :*

(1) *at the large centres;*

(2) *at small and medium sized stations ?*

In particular, in the case of the latter, is it possible to reduce, or even do away with the staff, by applying to the intermediate stations between the large centres, the methods used at stations of similar importance, worked under simplified operating methods on secondary lines ?

Answers.

The railways mention the following ways of reducing the number of employees at large stations :

1. *Rational organisation of the work,* called by certain railways « job-analysis ». On the *Belgian National Railways Co.* special gangs check the time taken by the staff in carrying out their duties, following each employee in turn. When some are found to be insufficiently employed, the work is distributed to others, by a more rational organisation.

On certain railways, such as the *British Railways* and the *Great Southern* of Eire, the combining of different jobs seems to be prevented to some extent by the agreements between the Companies and the Trade Unions. The *Great Southern Railways* fix the minimum station staff required for normal traffic. This is increased by temporary staff when there is an increase of traffic. The station master draws up each week statements justifying the staff employed relatively to the traffic (tonnage-number of wagons).

2. *Mechanisation of office work and handling.* The use of lifts for luggage and mechanical or electric trolleys is fairly general.

The *British Railways* use equipment called the « Passimeter » which enables an employee to issue tickets to those entering the station and collect them from those leaving. The *London Passenger Transport Board* has equipped its stations with automatic ticket machines, which reduces the work to be done in the booking offices.

3. *Limiting the hours during which stations remain open.* This limitation is generally closely connected with the organisation of the train services.

4. *Dispensing with the marshalling of wagons in certain junction stations,* and having such work done in special shunting and marshalling yards. This method of simplification is used by the *Belgian National Railways Company;* it makes it possible to economise on staff, but often involves an increase in the train or wagon mileage.

It should be noted that the railways

state that these methods of simplification are not confined to important lines, but are applied both at the large, medium sized and small stations on secondary lines.

In the latter, savings can be obtained by combining the duties of the staff; for example the practice of having a separate accountancy service has generally been given up. Moreover, like on the secondary lines, the hours during which stations remain open have been limited, and certain stations have been put under other more important stations.

QUESTION XIII. — *What is the minimum to which the train staff can be reduced ?*

In the case of the driving staff, when the technical characteristics of the method of traction used (electric locomotive, railcar, etc.) enable the trains to be driven by a single man, under what conditions do you consider this is compatible with safety ?

When the train staff is not required in connection with the train services (passenger service, parcels, etc.), is such staff essential from the point of view of safety ? Can it be reduced to a single man, or even dispensed with, the driver then being responsible for the corresponding duties ?

Answers.

On steam trains there are generally two men; the driver and the fireman. On the *Nizam's State Railway,* however, there are three men, as there are two firemen.

One man suffices on the internal combustion engined railcars or electric motor coaches, but a device known as the « dead man's handle » is provided and the driver's compartment can be reached from the train.

On the electric locomotives of the *British Railways* and the *London Passenger Transport Board,* there are two men. The latter Company makes use of the second man for such work as coupling and uncoupling.

It is becoming more and more general to employ only one conductor on a train; a second conductor is only employed in the case of very long passenger trains.

The *Pennsylvania Railroad* and the *Egyptian State Railways* still employ one or more brakesmen, even on passenger trains.

These railways consider that it is necessary to employ this number of men for reasons of safety, especially to protect the trains in case of breakdown.

QUESTION XIV. — *To what extent is it possible to reduce the cost of level crossing keepers or even dispense with keepers on the important and average lines?*

Answers.

The chief measures taken to reduce the cost of protecting level crossings are :

1. Eliminating the level crossing by diverting the road or building bridges;
2. Protecting the level crossing from a distance, or dispensing with keepers altogether after improving the visibility or installing automatic light signals;
3. Only having the crossings protected at certain hours of the day, after taking special safety precautions.

Most of the railways have applied one or several of these measures. There are level crossings, on all these railways, at which keepers have never been employed, because the visibility is good and the traffic small. Warning signs or posts are generally erected, to draw the attention of road users to these crossings.

The railways protect their level crossings according to the amount of rail and road traffic and the visibility. No standard classification of level crossings into different categories is mentioned. The *Belgian National Railways Company* reports, however, that it is proposed to replace keepers by automatic light signals :

1. When less than 100 children use the level crossing daily;

2. On lines where the autorised speed is higher than 100 km. (62 miles) an hour and the traffic index figure less than 5 000;

3. On lines where the authorised speed is under 100 km. an hour and the traffic index figure is less than 10 000.

The traffic index figure is taken to be the number obtained by multiplying the number of vehicles by the number of trains using the level crossing in 24 hours.

The laws require the *British Railways* to employ keepers at all level crossings on important lines. No economies can therefore be made, protection from a distance not being resorted to.

QUESTION XV. — *Have you prepared any balance sheets showing concrete examples of the savings obtained by systematic simplification of the working on important and average lines ?*

Answers.

All the railways replied in the negative.

C. — Simplified working of secondary lines.

QUESTION XVI. — *Can the secondary lines worked according to simplified methods be classified into various categories, for example :*

(a) *lines with both passenger and goods trains;*

(b) *lines where the passenger services have been discontinued, so that only goods trains are worked over them ?*

What characteristics can be used as a basis for such a classification ?

Are different principles applied to the simplification of each category ?

Answers.

Most of the railways replied that it would be possible to classify the lines in this way, but that the same principles of maintenance and simplification apply to the two categories. The choice of the method of working depends on the volume and kind of traffic.

On lines served only by goods trains, and even on certain other lines which always show a loss the *Belgian National Railways Company* dispenses with keepers at all the level crossings.

At these crossings the trains have to slow down to 5 km. (3 miles) an hour, and whistle before reaching the crossing and while passing it in order to warn the road users (see *Question XXI); if need be trains have to stop before reaching level crossings where the visibility is poor.

Certain railways (the *Nizam's State Railway*, the *Bombay, Baroda and Central India Railway*, and the *County Donegal Railway)* carry passengers and goods over all their lines. If need be composite trains are run.

The classification in question does not apply therefore to these Systems.

QUESTION XVII. — *Have you handed over certain categories of secondary lines to private undertakings (light railways, other transport undertakings, etc.), or have you considered taking such a step ?*

Under what conditions is this done ?

Answers.

All the railways replied in the negative.

QUESTION XVIII. — *Has the complete abandonment of existing lines been carried through, or considered ?*

If so, on what arguments was this decision based ? What has become of the equipment of such lines ?

Answers.

Only the *Nizam's State Railway,* the *Egyptian State Railways* and the *County Donegal Railways* replied in the negative. The other railways' affirmative replies can be summed up as follows :

Lines or sections of lines have been abandoned when the fall in traffic led to operating losses which were considered permanent. The losses were due to the fact that competitive methods of transport were preferred by the public and took away part of the traffic, or because the industrial and commercial activity of the district had definitely declined.

The equipment of such lines was removed for employment on other lines, or sold, and the buildings let or sold. Cases of lines being completely abandoned are however rare.

On the *Belgian National Railways Company* and on the *Great Southern Railways* of Eire the closing down of a secondary line or section of line is considered when the statistics of receipts and expenditure show that the line is being worked at a loss, and when a comparison with the cost of other methods of transport is in favour of the latter. The *Belgian National Railways Company,* for example, has given up certain lines showing a loss, situated in the districts served by the *Belgian National Light Railways Company.* The latter's lines are all narrow gauge lines operated very economically. It owns special trucks which take standard-gauge wagons, thereby avoiding transhipment of goods.

QUESTION XIX. — *What rules are followed, for each category of secondary lines, for the simplification of the working, as regards :*

(1) *the fixed plant (track, buildings, signals, etc.);*

(2) *safe working (speed of the trains, train headway, crossings, etc.);*

(3) *the staff;*

(3*a*) *use of the station and train staff; extending the duties of this staff to cover the following duties : keeping the records, inspection, issuing tickets, collecting transport charges, working points, signals, level crossing gates, etc.;*

(3*b*) *use of additional temporary staff;*

(3*c*) *hours during which the staff is on duty;*

(3*d*) *use of persons not belonging to the Railway, such as watchmen for depots (caretakers) located either in the centre of the localities served, or in a station building no longer used;*

(3*e*) *use of the train driving staff.*

Answers.

1. *Fixed plant.* — On secondary lines, the design and maintenance of the fixed plant can be more summary than on the important lines, as the speed and weight of trains are lower.

The *British Railways,* for example, have reduced the standard of maintenance which is done by small permanent gangs, the work being completed by mobile gangs carried to the work in railcars, together with their tools and materials.

2. *Safe working.* — The signalling equipment is less extensive, or may even be practically suppressed.

The *American Railways* use the manual block system on secondary lines instead of the automatic block, or else replace the block system by the dispatching system.

Other railways use a telephone block system instead of the interlocked block. Others again are content with interlocking by means of a key instead of interlocking in a signal box on lines with very little traffic.

The safety equipment has been reduced to a much greater extent than on the important lines.

The *Belgian National Railways Company* takes the following measures :

— the number of passing stations is reduced to the minimum, and in such stations alone is the signalling retained; distant signals are suppressed or put out of use; the fixed indicator posts showing the successive distances from the signals are, however, maintained. Trials have even been made of working a line entirely without signals, this being of course a very unimportant local line. Trains have to meet at fixed places, only the station masters at both ends of the line being authorised to alter the meeting place after agreement by telephone with the guards of the two trains. The points are worked by the fireman or guard and locked by key.

3. *Staff.* — The simplification measures taken on the important and average lines also apply to the secondary lines. These are dealt with in Questions VIII, XII, XIII, XIV and XXI.

(a) Certain measures for reducing the regular staff apply more particularly to the secondary lines. On the *Belgian National Railways Company,* for example, on lines with very little traffic, the enginemen help with the weighing of goods, working of points and handling of parcels. On the *British Railways* the train staff of the goods trains sometimes includes a travelling signalman who works in the signal boxes while the trains are being shunted in the stations. In the evening and at week ends the staff of these trains sometimes work the gates at certain level crossings.

Several railways require their staff to work broken turns; for example the eight-hour day is spread over 12 hours with one or more periods of rest.

(b) Temporary staff is generally employed to complete the service every day when it exceeds the capacity of the regular staff, or when the latter have to be assisted during periods of heavy traffic.

(c) As on the important lines — but even more rigorously — the working hours on the secondary lines and in their stations are reduced to the strictly necessary minimum; everything possible is done to make it only necessary to keep them open for 16, or even 8 hours.

(d) The employment of *persons not belonging to the railway* is rare. Recourse is only had to them for tasks which in reality are outside railway operation properly speaking, such as keepers at level crossings, issuing tickets, watchmen (caretakers) at places having no station staff.

(e) As far as the train staff is concerned, the same steps are taken as on the main lines.

The enginemen are not generally used for accessory duties. The *Belgian National Railways Company* is an exception, as reported above, as well as the *Bombay, Baroda and Central India Railway.*

QUESTION XX. — *What are the characteristics of the motive power and rolling stock in use or under consideration for the working of secondary lines ?*

Answers.

No railway has made use of any special locomotives or rolling stock on the secondary lines up to the present. The reason given is that this would hamper the intensive and rational utilisation of the stock. However, it is the practice to use single railcars (steam or internal-combustion engined) and light locomotives on such lines in preference.

The *Belgian National Railways Company* has recently put into service a railcar of light construction specially designed for lines with little traffic. This car which is driven and operated by a single man, has a diesel or petrol 120-H.P.E. engine; its weight empty is 14 250 kgr. (31 400 lb.). Its speed is limited to 60 km. (37 1/2 miles) an hour because in this way the track is spared. On the other hand it has very rapid acceleration. The car is equipped with a luggage locker. There is only one class, and 80 passengers can be carried, 50 seated. Another type of light railcar, carrying 120 passengers, 80 seated, is shortly to be tested.

The same Company is studying the use of diesel locotractors, and recently gave an order for some steam tank engines with mechanical stokers which can be run by a single man. The characteristics of these engines are as follows :

Cylinders :	
Number	2.
Diameter	350 mm. (13 3/4").
Stroke	500 mm. (19 11/16").
Boiler pressure.	16 kgr./cm² (228 lb./sq. in.).
Barrel :	
Diameter	1.10 m. (3' 7 5/16").
Distance between tube plates.	2.500 m. (8' 2 7/16").
Superheater	18 elements, 25 × 31 mm. (1" × 1 7/32") diam.
Coal capacity	1 500 kgr. (3 300 lb.).
Water capacity	4.5 m³ (990 Br. gall.).
Weight, empty	28.5 t. (28 Engl. tons).
Weight in working order	36 t. (35.4 Engl. tons).

The *British Railways* use reversible passenger trains known as « push and pull trains ». The driving compartment is in the end vehicle which is fitted with the necessary equipment for operating the locomotive regulator.

On one section of a secondary line the *London Passenger Transport Board* has put into service electric coaches whose doors are operated by compressed air. The train staff is thereby reduced to one : the driver.

QUESTION XXI. — *What method is used for guarding level crossings on secondary lines ?*

Under what conditions is it permissible :

(a) *to entirely dispense with keepers, with or without additional safety measures (these, if any, to be specified);*

(b) *to employ keepers only at certain times, i. e. only when trains are due;*

(c) *to control level crossings from a distance ?*

Answers.

The replies received show that the measures taken are very much the same as on the important lines. Mention may however be made of certain savings particular to lines carrying little traffic.

1. Employment of women as crossing keepers;

2. Closing the gates at night. To open them, road users have to call up the keeper who lives at the crossing or nearby *(Belgium, Egypt)*.

3. Combining the duties of level crossing keeper with those of other members of the station staff;

4. The train staff protect the road while the train is passing the crossing. This method is not much used, but is found in *Belgium*, on the *Baltimore and Ohio Railroad* and on the *Great Southern Railways* of Eire.

5. One man and his family employed as level crossing keepers. In this way someone is on duty all the 24 hours of the day *(Great Southern Railways)*.

The *Egyptian State Railways* where crossing protection from a distance is not allowed, report the invention by one of their engineers of a system of automatic gate, which is now under trial.

On the *British Railways*, it is not legal to dispense with level crossing keepers, except on light railways.

In *Belgium*, dispensing with level crossing keepers on secondary lines is usually authorised by the authorities when :

1. The road user can see the train at a distance of 40 m. (130 ft.) when he himself is 7 m. (23 ft.) from the track;

2. The road traffic does not exceed 500 vehicles a day.

When there is no keeper, fixed road signs must be erected. This consists of posts and panels with a red light at night. The driver of the train is generally required to slow down to 5 km. (3 miles) an hour and whistle; he is warned of the approach of a level crossing by an indicator panel 50 m. (165 ft.) away.

There are no precise regulations about distant protection. As a general rule the gates are of the lifting arm type with warning bells.

QUESTION XXII. — *What commercial measures have been introduced to simplify the clerical work of the staff and to facilitate relations with the public :*

(a) *simplification of clerical work and forms;*

(b) *concentration of all clerical work of a line in one managing station;*

(c) *special arrangements with regular customers, with premises connected with the railways, etc., as regards applications for rolling stock, weighing operations, collection of charges, notification of arrivals, etc.;*

(d) *relations with the public at times other than when the staff is on duty at the station;*

(e) *drawing up of special simplified rates tables for the use of the train staff when issuing tickets, etc. ?*

Answers.

All the railways have reduced the number of printed forms and carefully studied them so as to limit the written work and simplify office work as far as possible. Such forms can be used for various purposes and are standardised. These simplifications are not confined to secondary lines.

Very often the accounts of several stations or a whole line are concentrated at one managing station, and the intermediate stations merely keep simple records of their receipts and expenditure. On certain Systems, however, the question of concentration of the clerical work does not arise; this is due to the geographical situation (too great a distance between stations, etc.). This is the case in particular on the *Egyptian State Railways*, the *Nizam's State Railway* and the *Bombay, Baroda and Central India Railway.*

Special arrangements with regular customers are rare. Important customers use cheques and other banking facilities to settle their accounts.

The *Great Southern Railways*, of Eire, state that their regular customers themselves prepare the waybills in duplicate, which saves work at the stations. One copy is kept at the station, and the charges added; the other is given back to the consignor as a receipt. This railway trusts its regular customers to state the contents, weight, etc. correctly.

When the station staff is off duty, customers can deal with the station master if he resides on the spot, or telephone to the managing station.

Several railways point out that contact with the public is maintained through agents who call on customers or meet them at commercial gatherings.

Generally, the train staff is given rates lists to enable them to issue tickets rapidly, at least on lines where simplified working is in operation.

QUESTION XXIII. — *Are other methods of transport used for carrying passengers and goods ?*

If so :

(a) *are special combined rates in force, enabling either method of transport to be used indifferently ?*

(b) *are these other methods of transport operated by the railway or by a third party ? If by a third party, under what conditions ?*

Answers.

Certain railways have their own road passenger services, and even, though more rarely, goods services. For example, the *Nizam's State Railway*'s passenger and goods road services cover 4 017 road-miles. The *Egyptian State Railways* operate some river services.

Even if they run their own road services, most of the railways have contracts and agreements with private road carriers.

On the *Belgian National Railways Company* the road services and cartage are contracted out for payment of a percentage of the receipts.

On the *Pennsylvania Railroad*, such contracts are based on the cost per vehicle in service or per hour of use.

There are no combined railway-road rates except on the *British Railways* and on the *Baltimore and Ohio Railroad*.

The *Egyptian State Railways* have combined railway-river rates; transport by rail is worked at the usual rates, and transport by water at 6/10ths thereof.

QUESTION XXIV. — *What co-ordination measures have been taken, possibly in agreement with other methods of transport already in existence, for the conveyance of passengers and goods ? What alterations in the rates, if any, have such measures involved ?*

Answers.

With the exception of those Companies mentioned below, the railways consulted replied that the measures taken are the same for all categories of lines.

On the *Belgian National Railways Company*, there are combined rates for the transport of goods by the standard-gauge and light railways; such rates cover the whole carriage distance; the standard-gauge railway rates increased by a small amount per tonne-kilometre are applied; certain stations issue combined tickets and season tickets valid over both Systems; the price charged equals the amount of the two individual rates.

On the *Nizam's State Railway*, the timetables of the trains and omnibus services have been co-ordinated.

Goods are carried by road to the main stations. These road services, though expensive to run, have been maintained because they act as feeders and increase the railway traffic.

There are separate rates for transport by road and rail, but these are adjusted to meet competition.

QUESTION XXV. — *Have you prepared any balance sheets, for concrete examples, of the savings obtained by the application of simplified methods of working to secondary lines ?*

Answers.

All the railways consulted replied in

the negative except the *Belgian National Railways Company,* which draws up the operating accounts for lines showing a deficit, after simplification. This is done to see if the estimated savings are indeed obtained. It is found that they are in most cases.

* * *

SUMMARY.

Under the persistent influence of an unfavourable financial position, due in the first place to uncontrolled competition between the different methods of transport, the Railway Administrations find themselves obliged constantly to endeavour to reduce their operating costs by every possible means and consequently introduce measures of economy in every field in so far as this is compatible with their legal obligations.

These obligations are generally the result of legal enactments going back to an epoch when railway transport hardly met with any competition. This virtual monopoly it no longer enjoys owing to the development of motor transport on land and sea, and the constant improvement of the roads and waterways at the expense of the community. As a result it is imperative to revise the laws and adapt them to present-day conditions, placing the railway upon an equal footing with its competitors, whilst at the same time safeguarding public interests.

This result can only be obtained by a sound co-ordination of transport, giving to each method of transport what it can fairly claim as its due in view of the conveniences it can offer its customers at a truly economic and advantageous figure.

Amongst the measures of economy capable of reducing railway operating costs, are some that apply to all categories of line, as follows :

1. Systematic revision of all the fixed plant in order to bring it in line with the strict requirements of the working, and simplify the service of such plant.

2. Detailed study of the train working and shunting; permanent check on the extent to which passenger trains are used and corresponding modification of the number and composition of the trains; increasing the load of goods trains; reducing the number of stops and shunting operations during the journey in the case of goods trains; use in serving small stations of rakes hauled by light locotractors.

3. Rational organisation of the work at all the stations by careful study and timing of all the work; avoiding any loss of time; mechanisation of handling, of ticket issuing, etc.; simplification of the clerical work and formalities with customers (direct communication by telephone, banking accounts, etc.); combining duties, especially in small stations, so that all the work can be done by a smaller staff working to full capacity; use of temporary staff.

4. Reducing the duration of the service on the line to the strict minimum.

5. Only opening small stations at certain hours of the day, to the best convenience of customers, who can always obtain access to the loading and unloading platforms, however; clerical work for such stations done by a neighbouring managing station; replacement of the staff at small stations with very little local traffic by caretakers, not on the permanent railway staff, but whose honesty can be relied upon and who will act as intermediary between the railway and its customers for a moderate compensation.

6. Organisation of road services, either operated by the railway itself, or by contract, or by agreement with private undertakings for carrying passengers in small numbers, and bringing goods of all descriptions to the railway, especially small consignments (less than full wagon loads), such services being

so worked that the transport time is reduced to the minimum.

The application of combined rates which enable customers to use either method of transport at will seems to be advantageous.

⁂

Additional measures of economy can be looked for on certain lines, according to the amount of traffic they carry; on most of the extensive railway systems, the lines have been classified into important or average lines and secondary lines.

This subdivision, which is generally made without taking financial considerations into account, is based exclusively on the tonnage carried and the speed of the trains; each railway groups its lines according to its own methods of working.

In this connection, it may be recommended to keep simple statistics, without any complicated records, enabling, however, exact accounts to be drawn up, permanently showing the efficiency of each line.

⁂

Additional measures of simplification applicable to important and average lines are :

1. Transport of passengers by railcars or electric trains;

2. Reduction of the train staff to the minimum compatible with the safety of train operation;

3. Operating the lines by the automatic block system or by centralised traffic control (C. T. C.); these systems are, however, very expensive to install.

4. Protecting level crossings from a distance; dispensing with keepers at level crossings :

(a) without any additional safety measures when the road traffic is small and the visibility good;

(b) with automatic light signals when the traffic is relatively important;

(c) after building over- or underbridges when the road traffic is very heavy, the cost of such structures being divided between the different methods of transport concerned.

⁂

Additional simplification measures applicable to secondary lines are :

1. Total or nearly total abolition of signals and simplification of the working by having fixed points for trains to meet, and a managing station master in sole charge of the service on the whole line in the case of important delays.

2. When the proportion of secondary lines of a system is sufficient to justify it, the utilisation of special extra light rolling stock : railcars, steam locomotives, locotractors, all designed to be driven by one man who is also as far as possible in charge of the passenger service, issuing or inspecting tickets, dealing with parcels, etc. (one-man car).

3. Dispensing with keepers at level crossings, provision of fixed road signs, slowing down the trains and whistling on approaching crossings.

4. Replacement of the station staff by travelling staff who go by train from one station to another, and the employment of the usual train staff for station duties.

5. Suppression of passenger railway services when these are so small that they can be worked more economically by omnibus.

6. Complete abandonment of the railway service, removal of the whole railway equipment, when there are other more advantageous methods of transport in existence or to be introduced, which are able to give the public nearly the same facilities as they formerly enjoyed.

[625. 113]

Railway curves.

A new method of dealing with track adjustments, solely by the aid of the versines diagrams,

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In the pamphlet « Courbes de Chemins de fer (1) — Raccordements paraboliques (Etude sans calcul intégral), implantation des jonctions dans les courbes de formes quelconques, déterminées par leurs diagrammes des flèches » (Railway curves — Parabolic transitions [without calculus], and the introduction of turnouts into curves of any shape, by means of versines diagrams), we have shown how, by making use of the basic principles of curve realignment through versine corrections, it is possible to derive quite simply, equations for transitions between tangents and circles, and between circles of different radii, in a comprehensive manner impossible by orthodox analysis.

In this article we propose to make it clear that these processes, hitherto employed only in the special case of curve realignement, constitute in fact a general method as important as, for example, graphic statics.

We shall show, in particular, that its employment affords an appreciable saving of time compared with the usual methods, while at the same time a much greater degree of accuracy is obtainable.

First of all we will recall the principles governing the adjustment of a curve :

(a) For any two neighbouring curves connecting the same tangents, the sum of the versines and the sum of the moments of these versines, with respect to any point in the alignment, are constant (2).

(b) The centres of gravity of the versines diagrams for these two curves have the same abscissa (3).

To the above principles we add the following (4) :

(c) Two curves of any shape, having the same central angle, have equal versines sums.

(d) The central angle of an arc of a curve of any profile, joining two straight sections (tangents), is equal to twice the sum of the versines divided by the length a of the equidistance (chord) :

$$\alpha = \frac{2 \Sigma_o^n f}{a}.$$

(e) The central angle of the portion of

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(1) Publisher : L. Eyrolles, Librairie de l'Enseignement technique, Paris.

(2) These principles were enunciated by Messrs. Lefort, Hallade, Dupuy.

(3) This principle was enunciated by Mr. Saint-Amand.

(4) See : « A new method of surveying lines on curves and of calculating the angle at the centre by means of the diagrams of the versines », *Bulletin of the Railway Congress*, June 1936.

an arc between two pegs, o and m, peg o being on the straight line, is equal to :

$$\omega = \frac{2\,\Sigma_o^{m-1} f + f_m}{a},$$

f_m being the versine at peg m, and a the equidistances (chord lengths) between pegs.

(f) The central angle of the portion of an arc between pegs m and p is equal to :

$$\beta = \frac{2\,\Sigma_o^{p-1} f + f_p}{a} - \frac{2\,\Sigma_o^{m-1} f + f_m}{a} =$$

$$= \frac{2\,\Sigma_m^{p-1}\, f + f_p - f_m}{a}.$$

(g) Let ABC and ABDC' (fig. 4) be two curves, of any shape, the first joining the tangents SA and SX, and the second the tangents S'A and S'X'. The straight sections SA and S'A being either coincident or parallel, the straight sections SX and S'X' make an angle γ with one another.

The central angle of the curve ABC is equal to :

$$\alpha = \frac{2\,\Sigma_c^{A} f}{a}\,.$$

The central angle of the curve ABDC' is equal to :

$$\alpha + \gamma = \frac{2\,\Sigma_{c'}^{A}\,\mathrm{F}}{a}\,.$$

f = versines of the arc AC

F = versines of the arc ABDC'

a = chord length between pegs

whence :

$$\gamma = \frac{2\,\Sigma_{c'}^{A}\,\mathrm{F}}{a} - \frac{2\,\Sigma_c^{A} f}{a}$$

and :

$$\frac{\gamma \cdot a}{2} = \Sigma_{c'}^{A}\,\mathrm{F} - \Sigma_c^{A} f.$$

Thus the difference between the versines sums of two curves, of any profile, is equal to half the product of the chord length, a, between pegs, and the angle γ (in radians).

(h) The ordinate of any point on a curve, expressed in terms of its versines diagram, is equal to twice the second summation of the versines, from the origin of the diagram up to the versine immediately before the point in question (¹),

(i) This ordinate is also equal to the moment of the area of the curvatures diagram, with respect to the point in question, between the origin and the point.

(j) The ordinate of a point on the tangent following the curve, not far from the tangent point itself, is equal to twice the second summation of the versines from the origin of the diagram up to the versine before the point in question, the latter possibly being zero.

(k) This ordinate is also equal to the moment of the area of the curvatures diagram for the curve, with respect to the point in question.

These rules are based on the assumption that the axis of the abscissæ of the graph coincide, either, with one of the two tangents joined by the curve, or, with one of the chords of the curve; in the latter case the first versine to be taken is the one between the chord in question and the following one.

Thus in every case we have :

$$y_n = 2\,\Sigma\Sigma_o^{n-1} f.$$

The limits between which these rules, and the above formula, apply are the

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(¹) See *Bulletin of the Railway Congress*, February 1934, June 1936. See also « Courbes de chemins de fer. Raccordements paraboliques (Etude sans calcul intégral) ». (Railway Curves. Parabolic transitions [without calculus], etc.) L. Eyrolles, publisher, Paris.

same as those for the formula $\frac{x^2}{2\,R}$ for a circle of radius R, and

$$\frac{x^3}{12\,p_R} = \frac{K\,x^3}{3a^2}\ (^1)$$

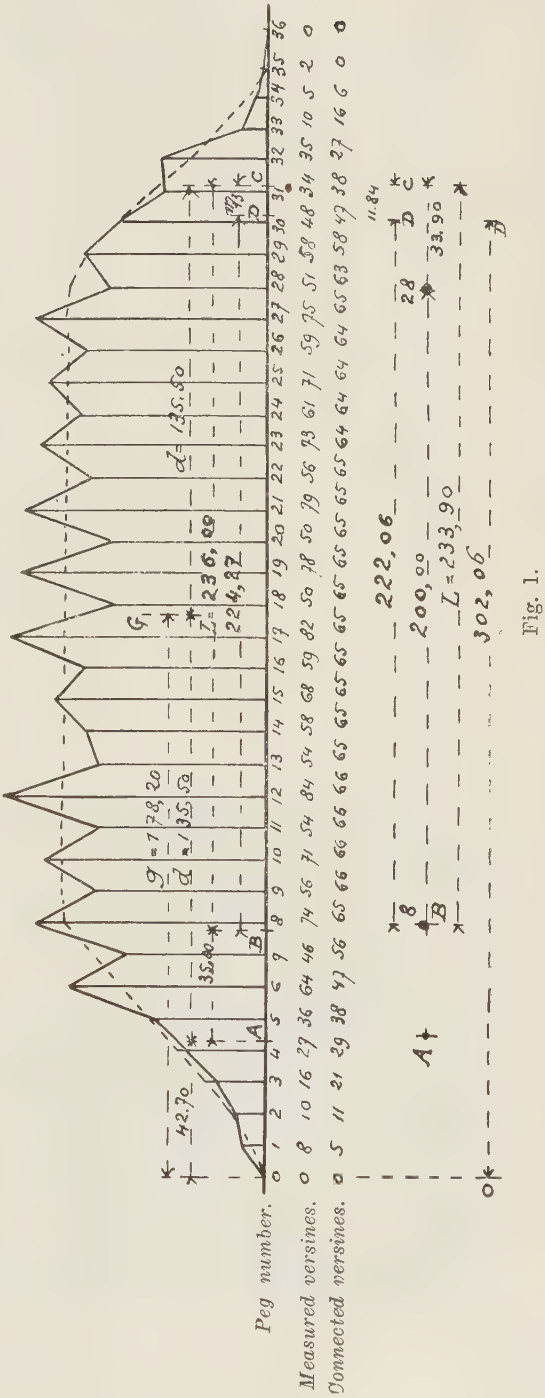
for the parabolic transition (spiral).

(l) All the theorems we have just propounded are applicable, as we have shown elsewhere, to layouts involving curves and reverse curves. It is sufficient to add a + sign to versines of curves the centres of which are on the right hand, for example, and, conversely, a — sign to versines of curves the centres of which are on the left hand, or inversely.

In order to show how these principles may be applied we will now examine a fairly common case of track adjustment.

Let a curve in a double-track line be represented by its versines diagram (fig. 1). In order to carry out certain works, the replacement, for example, of an ordinary bridge floor by one requiring a central girder, the inner track (including the tangent which follows the curve) must be shifted laterally, either parallel to itself or otherwise, by an amount governed by the circumstances of the case, and which may sometimes be as much as 2 m. It is proposed to calculate the data required to locate the new alignment.

If the usual methods were employed, namely, measurement of the deflection angle at the intersection of the tangents (often inaccessible), surveying the curve, studying the new scheme on paper and at the site, a week's work by a technical assistant would be hardly enough in many cases.



Peg number. 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
Measured versines. 0 8 10 16 27 36 64 46 74 56 71 54 84 54 58 68 59 82 50 78 50 79 56 73 61 71 59 75 51 58 48 34 35 10 5 2 0
Connected versines. 0 5 11 21 29 38 47 56 65 66 66 66 66 65 65 65 65 65 65 65 65 65 65 64 64 64 64 65 63 58 47 38 27 16 6 0 0
42,70
35,00
g = 778,20
d = 135,50
G
T = 236,00
224,82
d = 135,50
A
B
C
D
11.84
222,06
200,00
28
33,90
I = 233,90
302,06
8

Fig. 1.

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(1) See footnote (1), page 332.

The methods set out above to regulate require only a few hours of a [illegible] draughtsman's and a technician's work.

Track shifted parallel to itself

Let BC (fig. [illegible]) be a circular curve of radius R between two tangents SA and SC intersecting at S.

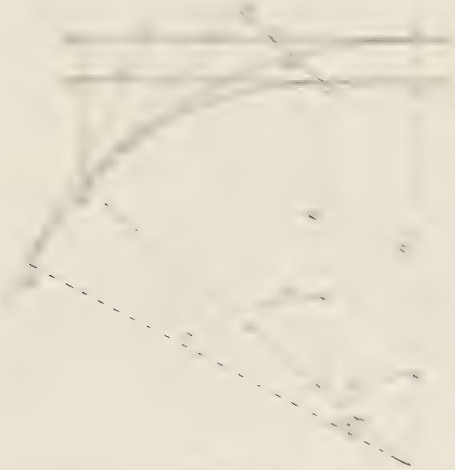

Fig. [illegible]

Let the tangent SC be displaced parallel to itself, to S'C', towards the inside of the curve by an amount CC' = h.

Let BD be a curve of radius R, having a common tangent at B with the curve BC, with line [illegible] and at D with the straight section [illegible].

The problem is to calculate the length of the arc BD, the value of the versine [illegible] and the throw required at each of the pegs of the arc BC in order to shift them into the new alignment BD.

Construct the curvatures diagram (fig. [illegible]) for the alignments BC and [illegible].

We now know that for the same distance [illegible], we have [illegible], whence [illegible] = R.

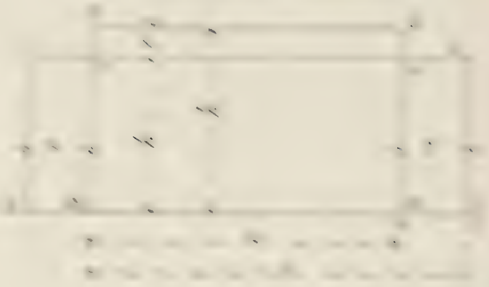

Fig. [illegible]

Let l denote the length of the arc BD and y the length of [illegible]. The total angles of the arcs BC and BD being equal, we have:

$$[illegible]$$

whence:

$$[illegible]$$

Putting:

$$[illegible]$$

we get:

$$[illegible]$$

On the other hand, [illegible].

We know that the lateral throw of peg [illegible] is equal to twice the sum of the moments of the differences between the versines of [illegible], the moments being taken, in relation to the point [illegible], or again, to the sum of the moments in relation to the point [illegible] of the areas [illegible] and [illegible].

The differences between the versines of the circular arcs BC and BD are negative between B and D while the differences between the versines of the arc BC and those of the straight line [illegible] [illegible] are positive.

Thus the area FHLM should be taken as negative and the area DHKC as positive.

On the other hand the lateral throw of the point C being towards the centre of the curve and therefore negative, we have:

$$-\varphi x\left(\frac{x}{2}-y\right)+y\,\frac{y}{R}\,\frac{y}{2}\ \text{[illegible]} = -A$$

$$-\frac{\varphi x^2}{2}-\varphi x y+\frac{y^2}{2R}=-A$$

but

$$\varphi=\frac{y}{R} \text{ whence } \varphi x y=\frac{y^2}{R}$$

and

$$-\frac{\varphi x^2}{2}-\frac{y^2}{2R}=-A, \quad \frac{\varphi x^2}{2}+\frac{y^2}{2R}=A$$

We now find this equation can also be obtained directly.

As a matter of fact, if we draw the tangent BD (fig. 2) we have:

DM — MB = DC = A.

MB is for practical purposes equal to $\frac{y^2}{2R}$, and the error introduced by calculating MD from the formula

$$\frac{x^2}{2}\left(\frac{1}{R_1}-\frac{1}{R}\right)=\frac{\varphi x^2}{2}$$

being equal to the difference between two practically equal errors is negligible, whence

$$\frac{\varphi x^2}{2}+\frac{y^2}{2R}=A$$

and:

$$R\varphi x^2+y^2=2RA.$$

but:

$$y=L-x, \quad \varphi=\frac{y}{Rx}=\frac{L-x}{Rx}$$

whence:

$$\frac{Rx^2(L-x)}{Rx}+(L-x)^2=2RA,$$

$$-Lx+L^2=2RA,$$

$$x=\frac{L^2-2RA}{L}=L-\frac{2RA}{L} \quad . \quad . \quad . \quad (1),$$

$$y=\frac{2RA}{L} \quad . \quad . \quad \varphi=\frac{2A}{x\frac{L}{R}}=\frac{2A}{x(\alpha-\beta)} \quad (2).$$

on the other hand:

$$L=\ \text{[illegible]}$$

a being the chord length between consecutive pegs.

These formulæ not being precise we will ascertain the error involved, by a practical example.

For R = 1000 m., A = 1.00 m., L = 138.11 m., x = [illegible] m., α = [illegible], β = 2° 17' 30'', we find:

x = [illegible], y = 7.35 m., [illegible] mm.

The exact solution, by trigonometry, gives:

$$y=\frac{A\sin(\alpha-\beta)}{1-\cos(\alpha-\beta)}=7.21 \text{ m.},$$

$$R_1-R=\frac{A}{1-\cos(\alpha-\beta)}=\ \text{[illegible]}$$

$$f_x=30.77 \text{ mm.}$$

The error, 7.35 — 7.21 = 0.14 m., not having any appreciable influence on the versines, may be neglected.

We will now return to the versines diagram of fig. 1 and consider the diagram, in full lines, of the unadjusted curve.

Application of the formulæ (1) and (2).

To apply the formulæ:

$$x=L-\frac{2RA}{L},$$

and

$$y = \frac{2\,RA}{L},$$

we are able to adjust the curve by the method known as « constant radius », or as shown by the dotted line in the diagram.

Adjustment by the « constant radius » method (1).

It is readily seen that the versines for the circular part of the curve fluctuate about an average of 65 mm., which value we will adopt.

Calculate the abscissa g, of the centre of gravity G of the diagram relatively to the peg *O*. We know that to do this we have merely to find the sum S of the moments of every versine relatively to the peg *O* and divide this moment sum by the sum s of the versines. We have :

$$S = 8 \times 1 + 10 \times 2 + 16 \times 3 + \ldots\ldots$$
$$\ldots\ldots \times 5 \times 34 + 2 \times 35 = 31\,394.$$

The sum s of the versines equals :

$$8 + 10 + 16 + \ldots\ldots + 34 +$$
$$+ 35 + 5 + 2 = 1762$$

whence :

$$g = \frac{S}{s} = \frac{31\,394}{1762} = 17.82$$

chord lengths = 178.20 m., and

$$d = \frac{1762}{65 \times 2} = 13.55$$

chord lengths = 135.50 m., since 65 mm. is the versine of the new circular arc.

d determines the position of the tangent points A and C, of the new curve, on either side of the centre of gravity.

By setting off from peg *O*, on the versines diagram (fig. 1), first 178.20 m. — — 135.50 m. = 42.70 m., then 42.70 + + (135.50 × 2) = 313.70 m., we obtain the tangent points A and C of the new curve.

The position of point D is given by the formula :

$$y = \frac{2RA}{L} = \frac{a^2\,A}{f_L},$$

since

$$R = \frac{a^2}{2\,f}.$$

The position of point B depends upon the length of the approach parabolic transition. If we adopt a length of 70 m. for this transition we get :

$$L = 271 - \frac{70}{2} = 236 \text{ m.}$$

By way of example take A = 1.80 m.

When L = 236 m., a = 10 m., A = 1.80, f = 65 mm., we find :

$$y = \frac{100 \times 1.80}{0.065 \times 236} = 11.73 \text{ m.}$$

Point D is 11.73 m. from point C, or 313.70 — 11.73 = 301.97 m. from peg *O*.

The length of the arc BD is equal to 236 — 11.73 = 224.27 m. Calculate the versine of the circular arc BD.

The formula :

$$x\,\delta = \frac{y}{R}$$

gives :

$$\frac{a^2}{2}\,x\,\delta = \frac{a^2}{2R}\,y$$

whence :

$$\frac{a^2}{2}\,\delta = \frac{a^2}{2}\left(\frac{1}{R_1} - \frac{1}{R}\right) =$$
$$= \frac{a^2\,y}{2\,R\,x} = \frac{f_R\,y}{x} = f_{R_1} - f_R.$$

For a = 10, y = 11.73, x = 224.27; f_R = 65 mm., we find :

$$f_{R_1} - 65 \text{ mm.} = \frac{11.73 \times 65}{224.27} =$$
$$= 3.3997 \text{ mm.}$$

Thus we have all the data required for calculating the new versines and completing the table of throws with the help of the formulæ derived in the article, « Diagrams of versines and superelevations » [1].

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(1) See « Méthodes de rectification du tracé des courbes de chemins de fer par correction des flèches » (Methods of realigning railway curves by correction of the versines). Publisher : L. Eyrolles, Librairie de l'Enseignement technique, Paris.

This method has the drawback of requiring calculations to at least three places of decimals, which is rather tedious. At the same time it possesses the advantage of being thoroughly systematic and requiring a minimum of attention from the Engineer, the work of the copying draughtsman or on the calculating machine being the most important.

Adjustment by the « varying radius » method.

We will now see how we can deal with this question, the curve being corrected by the « varying radius » method, as shown by the dotted versines diagram of fig. 1 and the horizontal line : (corrected versines) of this diagram.

We will not go into the details of the calculations involved by this adjustment, which are fully dealt with in the booklet « Méthodes de rectification du tracé des courbes de chemins de fer par correction des flèches » [2].

The corrected diagram shows that the circular part of the curve extends from peg 8 to peg 28.

Calculate the length of the parabolic transition by means of the formula :

$$X = \sqrt{\frac{3 \times 2\, \Sigma\Sigma f^{(3)}}{F}}$$

We find :

$$X = \sqrt{\frac{3 \times 2 \times \Sigma\Sigma_{35}^{29} f}{64}} =$$

$$= \sqrt{\frac{3 \times 2 \times 490}{64}} = 67.80 \text{ m.}$$

Consequently the tangent point C must be 33.90 m. from peg 28 and L = 200 + + 33.90 = 233.90 m.

If we keep A equal to 1.80 m. as previously, we have :

$$y = \frac{a^2 A}{f L} = \frac{100 \times 1.80}{0.065 \times 233.90} = 11.84 \text{ m.,}$$

and point D is located 11.84 m. from point C, that is to say at 233.90 + 80 — — 11.84 = 302.06 m. from peg *O*, or practically at peg 30.

The length of the arc BD is equal to 233.90 — 11.84 = 222.06 m., and the versine f_{R_1} is equal to :

$$65 + \frac{11.84 \times 65}{222.06} = 68.46 \text{ mm.}$$

Thus we obtain practically the calculated results with the « constant radius » method, so that we are at liberty to make use of either method, « varying radius » or « constant radius », according to choice. The latter, however, generally requires less time on the part of the technical staff.

We now make up Table 1, listing the throws. For this purpose, we retain the same versines for the parabolic transition at the approach to the corrected curve, for peg 8 not to be shifted.

If point D occurs at peg 30, the arc BD = 220 m. instead of 222.06 m., and we then have :

$$\alpha - \beta = \frac{220}{R_1} = \frac{2\, \Sigma_{36}^{9} f + f_8}{10} =$$

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[1] *Bulletin of the Railway Congress*, September 1930.

[2] L. Eyrolles, publisher, Paris.

[3] « Courbes de chemins de fer. Raccordements paraboliques (sans calcul intégral), etc. ». L. Eyrolles, Publisher, Paris. It can be seen from the corrected versines diagram of fig. 1 (dotted line), that if it is not desired to use this formula, the parabolic transition at the end of the curve extends approximately from peg 28 to within 8.00 m. from peg 34, that is for a distance of 68 m. Consequently L = 200 + 34 = 234.00.

Table of throws, No. 1.

Peg numbers.	Versines of the arc AC, *f*	Versines of the arc ABD, F	Differences *f* — F = δ	Summation of the δ's.	Half throws. — Summation of the figures in column 5.
1	2	3	4	5	6
0	0	0	0	0	
1	5	5	0	0	0
2	11	11	0	0	0
3	21	21	0	0	0
4	29	29	0	0	0
5	38	38	0	0	0
6	47	47	0	0	0
7	56	56	0	0	0
8	65	67	—2	—2	0
9	66	69	—3	—5	—2
10	66	69	—3	—8	—7
11	66	69	—3	—11	—15
12	66	69	—3	—14	—26
13	65	69	—4	—18	—40
14	65	69	—4	—22	—58
15	65	69	—4	—26	—80
16	65	69	—4	—30	—106
17	65	69	—4	—34	—136
18	65	69	—4	—38	—170
19	65	69	—4	—42	—208
20	65	69	—4	—46	—250
21	65	69	—4	—50	—296
22	65	69	—4	—54	—346
23	64	69	—5	—59	—400
24	64	69	—5	—64	—459
25	64	69	—5	—69	—523
26	64	70	—6	—75	—592
27	65	70	—5	—80	—667
28	63	70	—7	—87	—747
29	58	70	—12	—99	—834
30	47	35	+12	—87	—933
31	38	0	+38	—49	—1020
32	27	0	+27	—22	—1069
33	16	0	+16	—6	—1091
34	6	0	+6	0	—1097
35	0	0	0	0	—1097
36	0	0	0		—1097
	1762	1762			

$$= \frac{2\,(1\,762 - 272) + 65}{10} = 0.3045$$

$$R_1 = \frac{220}{0.3045} = 722.50\,\text{m.}, \quad f_{R_1} = 69.2\,\text{mm.}$$

The versine at point D will be equal to $\frac{69}{2} = 35$ mm. to the nearest millimetre, and that at peg 8 to $\frac{65 + 69}{2} = 67$ mm.

The other versines, up to peg 29, will vary between 69 and 70 mm., in such a way that the sum of the versines of the arc BD are equal to the versines of the actual curve.

The table of throws indicates for pegs 34 and 35, that is to say for the straight line SC, a throw of 1 097 × 2 = 2 194 mm. But our calculations are based on a maximum throw of 1.80 m., and we will now attempt to account for this difference.

The formulæ we have been using were derived for a pure circular arc joining, without transition curves, the tangents SA and SC, whilst the versines of the circular part of the diagram in fig. 1 are those of the original circle, shifted to allow of inserting transitions at the approach to, and exit from, the curve.

But to introduce a parabolic transition (fig. 2) between a circular arc AC and the straight sections SA and SC, the arc AC must be shifted parallel to itself towards the centre of the curve by the amount :

$$\frac{p^2}{6\,R} = \frac{f\,p^2}{3\,a^2}$$

The straight section DC' being shifted by the same amount, SC attains a final shift equal to :

$$CC' + \frac{f\,p^2}{3\,a^2}.$$

If we put $f = 65$, $p = 35$ m., we obtain a throw of 1 800 + 266 = 2 066 or a half-throw of 1 033 mm., giving a difference of 1 097 — 1 033 = 64 mm. This discrepancy is due to the fact that the versines of the circular portion of the corrected curve represented by the versines diagram (dotted line) of fig. 1, are not absolutely constant, and that its transitions are not theoretically correct.

It would be possible, by modifying a few of the versines by ± 1 mm., to eliminate this discrepancy, but there would be no point in so doing as it is necessary to introduce a Nordling transition curve between the arc BD and the straight section S'C'.

For this transition to have a length of 80 m., the straight section S'C' must be shifted parallel to itself and towards the outside of the curve by :

$$\frac{\overline{40}^2 \times 70}{3 \times \overline{10}^2} = 373\ \text{mm.}$$

But the table of throws indicates for the straight section SC a throw equal to 1.097 × 2 = 2.194 m. towards the centre; combining this with a throw, towards the outside, of 0.373 m., we finally arrive at a nett throw towards the centre of :

$$2.194 - 0.373 = 1.821\ \text{m.},$$

instead of 1.800 m.

It is a simple matter to eliminate this discrepancy by altering one or two of the versines for the arc BD or the transition curve by ± 1 mm. in such a way that the versine-sum for the arc AD remains equal to that for the arc AC.

Application of formula (3) :

$$y = \frac{2\,A}{\alpha - \beta}.$$

We will apply this formula to the case

of the uncorrected curve represented by the full lines in the versines diagram of fig. 1.

An inspection of this diagram reveals that the transition at the curve approach ends at peg 8 and that at the exit ends at peg 28.

Determining the length of the parabolic transition at the exit by the formula :

$$X = \sqrt{\frac{3 \times 2\,\Sigma\Sigma_{36}^{29} f}{65}},$$

we obtain 67.25 m., which enables us, without any adjustment of the circular portion of the curve, to fix the point D practically at peg 30.

Let the arc BD have a length of 300 — 80 = 220 m. We then have :

$$\alpha - \beta = \frac{220}{R_1} = \frac{2\,\Sigma_{36}^{9} f + f_8}{10},$$

$$\frac{2\,\Sigma_{36}^{9} f + f_8}{10} = \frac{2 \times 1481 + 74}{10} = 0.3036$$

whence :

$$\frac{220}{R_1} = 0.3036,$$

$$R_1 = \frac{220}{0.3036} = 724.64 \text{ m.}$$

$$\text{and } f_{R_1} = 69 \text{ mm.}$$

It will be realised that this very quick method, using the uncorrected curve, is only valid provided the versines of the circular portion of the curve fluctuate about an average value, which is quite easily verified.

Method based on the direct calculation of ordinates.

There is also another method which can be adopted.

Assuming that the arc AC (fig. 2) represents the layout corresponding to the versines diagram in fig. 1, and that point B occurs at peg 8, the end of the parabolic transition at the curve approach, we have :

$$BT - BV = A,$$

$$BT = 2\,\Sigma\Sigma_{36}^{9} f,$$

$$BV = \frac{x^2}{2R_1},$$

f being the versines of the arc BC from peg 36 to peg 9,

and x the length of the arc BD of radius R_1.

Consequently : $A = 2\,\Sigma\Sigma_{36}^{9} f - \dfrac{x^2}{2\,R_1}$,

for the errors involved in calculating the ordinates BT and BV with these approximate formulæ, being almost equal, will cancel each other.

On the other hand, $\alpha - \beta$ being the central angle of the arc BC, or the arc BD, we have :

$$\alpha - \beta = \frac{x}{R_1}, \quad \frac{1}{R_1} = \frac{\alpha - \beta}{x}, \quad R_1 = \frac{x}{\alpha - \beta},$$

$$f_1 = \frac{a^2}{2\,R_1} = \frac{a^2(\alpha - \beta)}{2\,x}$$

$$\frac{x^2}{2\,R_1} = \frac{x^2}{2} \times \frac{\alpha - \beta}{x} = \frac{x(\alpha - \beta)}{2},$$

and

$$A = 2\,\Sigma\Sigma_{36}^{9} f - \frac{x(\alpha - \beta)}{2},$$

whence :

$$x = \frac{2\,\Sigma\Sigma_{36}^{9} f - A}{\dfrac{\alpha - \beta}{2}}.$$

Applying these formulæ to the example we have already cited, we find :

$$2\,\Sigma\Sigma_{36}^{9} f - A =$$

$= 17.884 \text{ m.} \times 2 - 1.80 \text{ m.} = 33.968 \text{ m.};$

$$\alpha - \beta = \frac{2\,\Sigma_{36}^{9} f + f_8}{a} =$$

$$= \frac{1.481 \times 2 + 0.074}{10} = 0.3036;$$

$$x = \frac{33.968}{\frac{0.3036}{2}} = 223.76 \text{ m.},$$

$$f_{R_1} = \frac{\overline{10}^2 \times 0.3036}{223.76 \times 2} = 0.068.$$

These results agree quite well with those found previously.

Track shifted obliquely.

Let the straight line SC (fig. 4) be shifted to S'C' so that the two meet at an angle γ, and that CC' = A.

Let AC be a circular curve of radius R between the two tangents SA and SC, intersecting at S.

Let BD be a curve of radius R_1 having a common tangent with the circle AC at B and touching the straight line S'C' at D.

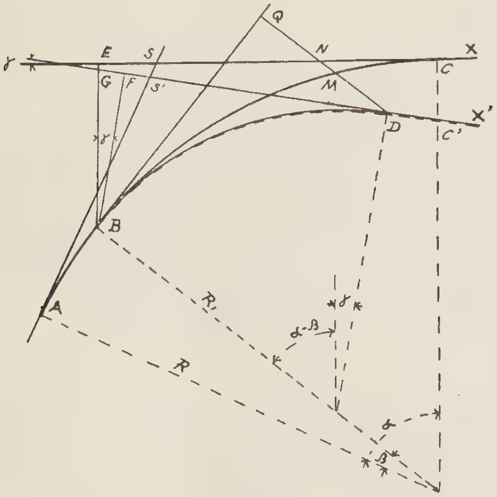

Fig. 4.

We propose to calculate the length of the arc BD, the value of the versine f_{R_1} and the throws required at each peg of the arc BC to shift it to the new alignment BDC'.

Considering the offset to the tangent BQ, we have :

$$ND = QD - QM + MN,$$

$$ND \approx CC' = A - y \tan \gamma, \quad QD = \frac{x^2}{2\,R_1},$$

$$QM = \frac{x^2}{2\,R}, \quad MN = \frac{y^2}{2\,R},$$

x being the length of the arc BD, and $y \approx MC$,

whence :

$$A - y \tan \gamma = \frac{x^2}{2\,R_1} - \frac{x^2}{2\,R} + \frac{y^2}{2\,R},$$

for all practical purposes, since the errors involved in calculating QD and QM, being almost equal, tend to cancel each other.

The same equation is obtained if CC' is expressed as the offset between the two curves BDC' and BC.

This offset is, in fact, equal to the difference between the moment about C' of the area of the curvatures diagram for the alignment BDC', and the moment about C of the area of the curvatures diagram for the alignment BC.

In the first case the moment is equal to :

$$x \times \frac{1}{R_1}\left(\frac{x}{2} + y\right) = \frac{x^2}{2\,R_1} + \frac{x\,y}{R_1},$$

and in the second case, to :

$$(x + y)\,\frac{1}{R}\left(\frac{x + y}{2}\right) = \frac{x^2}{2\,R} + \frac{y^2}{2\,R} + \frac{x\,y}{R},$$

whence :

$$CC' = \frac{x^2}{2\,R_1} + \frac{x\,y}{R_1} - \frac{x^2}{2\,R} - \frac{y^2}{2\,R} - \frac{x\,y}{R}.$$

The central angle of the alignment BD is equal to the central angle of the alignment BC, plus γ, whence :

$$\frac{x+y}{R} + \gamma = x \times \frac{1}{R_1} = \frac{x}{R} + \frac{y}{R} + \gamma,$$

$$\frac{x\,y}{R_1} = \frac{x\,y}{R} + \frac{y^2}{R} + y\,\gamma$$

$$\text{and } CC' = A = \frac{x^2}{2\,R_1} + \frac{x\,y}{R} + \frac{y^2}{R} +$$

$$+ \gamma y - \frac{x^2}{2R} - \frac{y^2}{2R} - \frac{x\,y}{R},$$

$$A - y\,\gamma = \frac{x^2}{2\,R_1} - \frac{x^2}{2\,R} + \frac{y^2}{2\,R}.$$

We have thus evolved the same equation as before, with the exception that γ in the second term of the left-hand side has been substituted for $\tan \gamma$, to which however it is practically equal, the angle γ always being small.

From the equation :

$$A - y\,\gamma = \frac{x^2}{2\,R_1} - \frac{x^2}{2\,R} + \frac{y^2}{2\,R}$$

we obtain, by putting :

$$\frac{1}{R_1} - \frac{1}{R} = \delta, \qquad \frac{\delta\,x^2}{2} + \frac{y^2}{2\,R} = A - y\gamma,$$

$$R\,\delta x^2 + y^2 = 2\,RA - 2\,R\,y\gamma,$$

but $y = L - x$, L being the length of the arc BC,

$$R\,\delta x^2 + (L - x)^2 = 2\,RA - 2\,R\gamma\,(L - x).$$

The equation :

$$x \times \frac{1}{R_1} = \frac{x}{R} + \frac{y}{R} + \gamma$$

gives :

$$x\left(\frac{1}{R_1} - \frac{1}{R}\right) = \frac{y}{R} + \gamma.$$

$$x\,\delta = \frac{y}{R} + \gamma,\ \delta = \frac{y}{R x} + \frac{\gamma}{x} = \frac{L - x}{R\,x} + \frac{\gamma}{x}.$$

Consequently :

$$R\,x^2\left(\frac{L - x}{R\,x} + \frac{\gamma}{x}\right) +$$

$$+ (L - x)^2 = 2\,RA - 2\,R\gamma\,(L - x)$$

$$\frac{R\,x^2\,L - R\,x^3}{R\,x} + \frac{R\,x^2\gamma}{x} + L^2 + x^2 -$$

$$- 2\,Lx = 2\,RA - 2\,R\gamma L + 2\,R\gamma\,x$$

$$x L + R\gamma x = L^2 - 2\,RA + 2\,R\gamma L$$

$$x = \frac{L^2 - 2\,RA + 2\,R\gamma L}{L + R\gamma} \quad \ldots\ldots \quad (4),$$

$$y = L - x = \frac{2\,RA - R\gamma L}{L + R\gamma} \quad \ldots\ldots \quad (5) =$$

$$= \frac{2A - \gamma L}{\frac{L}{R} + \gamma} = \frac{2\,A - \gamma L}{\alpha - \beta + \gamma} \quad \ldots\ldots \quad (6).$$

From

$$\delta = \frac{L - x}{R\,x} + \frac{\gamma}{x}$$

we get :

$$\frac{a^2}{2}\,\delta = f_{R_1} - f_R = \frac{a^2}{2}\left(\frac{L - x}{R\,x} + \frac{\gamma}{x}\right).$$

These formulæ not being strictly accurate, we will ascertain the error involved, in an actual case.

When $R = 1\,000$ m., $L = 471.24$ m., $A = 2.88$ m., $\gamma = 33'$, $\alpha = 30°$, $\beta = 3°$, we find : $x = 468.67$ m., $y = 2.57$ m., $f_{R_1} = 51.29$ mm. The exact solution, by trigonometry, yields :

$$y = \frac{(R - R_1)\sin(\alpha - \beta)}{\cos\gamma} - R_1 \tan\gamma = 2.33 \text{ m.},$$

$$R_1 = \frac{R\,[\,1 - \cos(\alpha - \beta) + \sin(\alpha - \beta)\tan\gamma\,] - A}{\frac{1}{\cos\gamma} - \cos(\alpha - \beta) + \sin(\alpha - \beta)\tan\gamma} = 974.27 \text{ m.},$$

$$f_{R_1} = 51.3 \text{ mm.}$$

The difference, 2.57 m. — 2.33 m. = = 0.24 m., is negligible, since it has no effect on the value of the versines of the arc BD.

The application of formulæ (4), (5), and (6) to a curve represented by any diagram of versines such as that of fig. 1 (full lines) will be made as we have already shown, in the case of the straight line SC being shifted parallel to itself.

Method based on the direct calculation of the ordinates.

Assuming that the arc AC (fig. 4) represents the alignment defined by the versines diagram (full lines) of fig. 1, and that point B is located at peg 8, the end of the transition at the approach to the curve, we have :

$$\mathrm{GE} = \mathrm{BE} - \mathrm{BG}$$

$$\mathrm{GE} = \mathrm{CC'} - \mathrm{EC} \tan \gamma = \mathrm{A} - \mathrm{EC} \tan \gamma$$

$$\mathrm{BE} = 2 \Sigma\Sigma_{36}^{9} f, \quad \mathrm{BG} = \frac{\mathrm{BF}}{\cos \gamma},$$

$$\mathrm{BF} = \frac{x^2}{2\,\mathrm{R}_1}, \quad \mathrm{BG} = \frac{x^2}{2\,\mathrm{R}_1 \cos \gamma},$$

whence :

$$\mathrm{A} - \mathrm{EC} \tan \gamma = 2\, \Sigma\Sigma_{36}^{9} f - \frac{x^2}{2\,\mathrm{R}_1 \cos \gamma}.$$

The central angle of the arc BD is equal to the central angle of the alignment BC plus the angle γ.

The central angle of the curve BC is equal to :

$$\frac{2\, \Sigma_{36}^{9} f + f_8}{10},$$

whence :

$$\frac{2\, \Sigma_{36}^{9} f + f_8}{10} + \gamma = \frac{x}{\mathrm{R}_1},$$

$$\frac{1}{\mathrm{R}_1} = \frac{2\, \Sigma_{36}^{9} f + f_8}{10x} + \frac{\gamma}{x}.$$

Finally

$$\mathrm{A} - \mathrm{EC} \tan \gamma =$$

$$= 2\, \Sigma\Sigma_{36}^{9} f - \frac{x^2}{2 \cos \gamma} \left(\frac{2\, \Sigma_{36}^{9} f + f_8}{10x} + \frac{\gamma}{x} \right)$$

$$= 2\, \Sigma\Sigma_{36}^{9} f - \frac{x}{2 \cos \gamma} \left(\frac{2\, \Sigma_{36}^{9} f + f_8}{10} + \gamma \right),$$

and

$$x = \frac{(2\, \Sigma\Sigma_{36}^{9} f + \mathrm{EC} \tan \gamma - \mathrm{A})\, 2 \cos \gamma}{\frac{2\, \Sigma_{36}^{9} f + f_8}{10} + \gamma}.$$

Knowing the value of x, we can now calculate R_1 and, therefore, $f_{\mathrm{R}1}$ from the formula :

$$\frac{x}{\mathrm{R}_1} = \frac{2\, \Sigma_{36}^{9} f + f_8}{10} + \gamma.$$

When the curve AC is made up of several parts of widely different radii, the calculation of EC is difficult, and the process is therefore not to be recommended : it is preferable to correct the curve by either the « constant radius » method or by the « varying radius » method; in this case the difference between the versines should not exceed 1 to 2 mm.

We will now apply the method to the curve represented by the versines diagram in fig. 1 :

Substituting into the formulæ :

$$x = \frac{\mathrm{L}^2 - 2\,\mathrm{RA} + 2\,\mathrm{R}\gamma\mathrm{L}}{\mathrm{L} + \mathrm{R}\gamma},$$

$$y = \frac{2\,\mathrm{RA} - \mathrm{R}\gamma\mathrm{L}}{\mathrm{L} + \mathrm{R}\gamma},$$

$$f_{\mathrm{R}_1} - f_{\mathrm{R}} = \frac{a^2}{2} \left(\frac{\mathrm{L} - x}{\mathrm{R}x} + \gamma x \right)$$

the values : $a = 10$ m., $\mathrm{A} = 2.88$ m., $\gamma = 33'$,

— we get for L = 233.90 m. :
$x = 222.70$ m., $y = 11.20$ m., $f_{R1} =$ 70.4 mm.,

— and for L = 236.00 m. :
$x = 224.96$ m., $y = 11.04$ m., $f_{R1} =$ 70.3 mm.

From the formulæ :

$$x = \frac{(2\,\Sigma\Sigma^{9}_{36}\,f + \mathrm{EC}\tan\gamma - \mathrm{A})\,2\cos\gamma}{\dfrac{2\,\Sigma^{9}_{36}\,f + f_8}{10} + \gamma}$$

$$\frac{1}{\mathrm{R}_1} = \frac{2\,\Sigma^{9}_{36}\,f + f_8}{10\,x} + \frac{\gamma}{x},$$

putting EC = BC = 233.90 m., we get : $x = 224.35$ m., $R_1 = 716$ m., $f_{R_1} =$ 70 mm.

None of these results differ by more than a negligible amount.

Having compared these formulæ, we return to our problem, letting the arc AC (fig. 4) be the alignment represented by the versines diagram in fig. 1 (dotted lines), the point C coinciding with peg 34, and making A = 2.88 m., $\gamma = 33' = 0.0096$.

We have seen in dealing with the first example that L = 233.90 m., the circular portion of the curve extending from peg 8 to peg 28; therefore :

$$y = \frac{2\,\mathrm{RA} - \mathrm{R}\gamma\mathrm{L}}{\mathrm{L} + \mathrm{R}\gamma} = 11.20\,\mathrm{m.}$$

Point B being at peg 8, point D will be at 80 + 233.90 — 11.20 m. = 302.70 m. from peg *O*, that is, practically at peg 30.

But in that case BD will equal 300 — 80 = 220.00 m. We then have :

$$\frac{220}{\mathrm{R}_1} = \frac{2\,\Sigma^{9}_{36} f + f_8}{10} + \gamma =$$

$$= 0.3045 + 0.0096 = 0.3141$$

$$\mathrm{R}_1 = \frac{220}{0.3141} = 700. \quad f_{\mathrm{R}_1} = 71.43\,\mathrm{mm.}$$

We can now complete the table of throws, No. 2, retaining the versines of the transitioned approach (as far as peg 7) so that peg 8 requires no throw.

The versine at peg D must equal $\frac{71.43}{2} = 35.71$ or 36 mm. in round figures, and that at peg 8, $\frac{65 + 71.43}{2} =$ = 68 mm.

The other versines, up to peg 29, will have values varying between 71 and 72 mm., in order to make the difference between the versines sum for the arc AC and that for the arc AD (on the alignment ABDC') equal to :

$$\frac{\gamma a}{2} = \frac{0.0096 \times 10}{2} = 48\,\mathrm{mm.},$$

point C being situated at peg 34, which is common to the arc AC and the straight line SX. In this way the difference between the throws at pegs 34 and 35, determining the direction of the straight line S'X', is equal to 48 × 2 = 96 mm., and the angle between SX and S'X' is equal to :

$$\gamma = \frac{96}{10} = 9.6\,\mathrm{mm.}$$

The versines sum for the arc AC being equal to 1 762 mm., the versines sum for the arc ABD should be equal to 1 762 + + 48 = 1 810 mm.

The table of throws, No. 2, shows negative throws at pegs 34 and 35, equal respectively to :

$$1\,799\ \mathrm{mm.} \times 2 = 3\,598\ \mathrm{mm.}$$

$$1\,847\ \mathrm{mm.} \times 2 = 3\,694\ \mathrm{mm.},$$

whence :

$$\frac{3694 - 3598}{10} = 9.6\,\mathrm{mm.}$$

equal, in fact, to the value of the angle γ between the two tangents SC and S'C'.

Table of throws, No. 2.

Peg numbers. 1	Versines of the arc AC, *f* 2	Versines of the arc ABD, F 3	Differences $f - F = \delta$ 4	Summation of the δ's. 5	Half throws. — Summation of the figures in column 5. 6
0	0	0	0		
1	5	5	0	0	0
2	11	11	0	0	0
3	21	21	0	0	0
4	29	29	0	0	0
5	38	38	0	0	0
6	47	47	0	0	0
7	56	56	0	0	0
8	65	68	—3	0	0
9	66	71	—5	—3	—3
10	66	71	—5	—8	—11
11	66	71	—5	—13	—24
12	66	71	—5	—18	—42
13	65	71	—6	—23	—65
14	65	71	—6	—29	—94
15	65	71	—6	—35	—129
16	65	71	—6	—41	—170
17	65	71	—6	—47	—217
18	65	71	—6	—53	—270
19	65	71	—6	—59	—329
20	65	71	—6	—65	—394
21	65	71	—6	—71	—465
22	65	72	—7	—77	—542
23	64	72	—8	—84	—626
24	64	72	—8	—92	—718
25	64	72	—8	—100	—818
26	64	72	—8	—108	—926
27	65	72	—7	—116	—1042
28	63	72	—9	—123	—1165
29	58	72	—14	—132	—1297
30	47	36	+11	—146	—1443
31	38	0	+38	—135	—1578
32	27	0	+27	—97	—1675
33	16	0	+16	—70	—1745
34	6	0	+6	—54	—1799
35	0	0	0	—48	—1847
36	0	0	0	—48	—1895
	1762	1810			

In order to introduce a Nordling transition curve, 100 m. long, between the tangent S'X' and the arc BD, the straight line S'X' must be shifted parallel to itself, towards the outside of the curve, by the amount :

$$\frac{f\,p^2}{3\,a^2} = \frac{72 \times \overline{50}^2}{3 \times 100} = 600 \text{ mm.}$$

The throw at peg 34 becomes 1 799 × × 2 — 600 = 2 998 mm. instead of the 2.88 m. required. It is therefore necessary to reduce the half-throw at peg 34 by :

$$\frac{2\,998 - 2.88}{2} = 0.059 = 59 \text{ mm.}$$

which is quite easily done by modifying a few of the versines by ± 1 mm., but in such a way that the difference between the versines sum for the arc ABD and that for the arc AC remains equal to 48 mm.

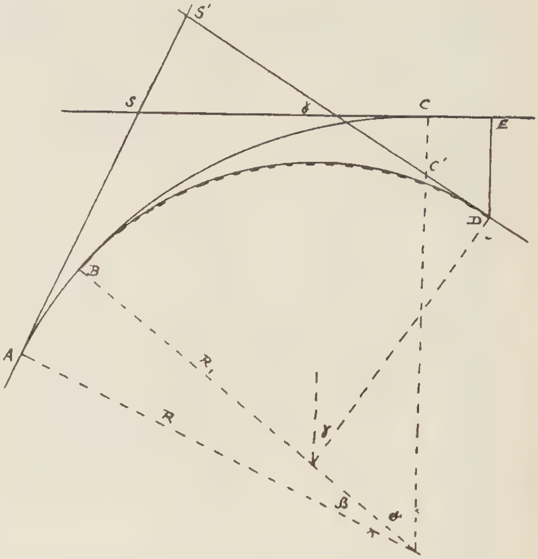

Fig. 5.

Two examples having been dealt with at length, we will now briefly review one or two variations.

In the case of fig. 5, the trigonometrical solution yields :

$$R_1 = \frac{R\,(1 - \cos(\alpha - \beta) + \sin(\alpha - \beta)\tan\gamma) - A}{\dfrac{1}{\cos\gamma} + \sin(\alpha - \beta)\tan\gamma - \cos(\alpha - \beta)}$$

$$C'D = R_1 \tan\gamma - \frac{(R - R_1)\sin(\alpha - \beta)}{\cos\gamma}, \qquad CE = R_1 \sin\gamma - (R - R_1)\sin(\alpha - \beta).$$

Using the versines diagram, we find :

$$x = \frac{L^2 - 2\,RA + 2\,R\gamma L}{R\gamma + L}, \quad y = \frac{R(\gamma L - 2\,A)}{R\gamma + L} = \frac{\gamma L - 2\,A}{\alpha - \beta + \gamma}.$$

In the case of fig. 6, the trigonometrical solution yields :

$$R_1 = \frac{A + R\,(1 - \cos(\alpha - \beta) - \sin(\alpha - \beta)\tan\gamma)}{\dfrac{1}{\cos\gamma} - \sin(\alpha - \beta)\tan\gamma - \cos(\alpha - \beta)}$$

$$C'D = \frac{(R_1 - R)\sin(\alpha - \beta)}{\cos\gamma} - R_1 \tan\gamma.$$

Using the versines diagram, we find :

$$x = \frac{L^2 + 2\,RA - 2\,R\gamma L}{L - R\gamma}, \quad y = \frac{R\,(2\,A - L\gamma)}{L - R\gamma} = \frac{2\,A - L\gamma}{\alpha - \beta - \gamma}$$

In the case of fig. 7, the trigonometrical solution yields :

$$R_1 = \frac{A + R\,[1 - \sin(\alpha - \beta)\tan\gamma - \cos(\alpha - \beta)]}{\dfrac{1}{\cos\gamma} - \sin(\alpha - \beta)\tan\gamma - \cos(\alpha - \beta)}$$

$$C'D = R_1 \tan\gamma - \frac{(R_1 - R)\sin(\alpha - \beta)}{\cos\gamma}$$

Using the versines diagram, we find :

$$x = \frac{2R\gamma L - L^2 - 2RA}{R\gamma - L}, \quad y = \frac{R(2A - \gamma L)}{R\gamma - L} = \frac{2A - \gamma L}{\gamma - (\alpha - \beta)}$$

In the case of fig. 8, the trigonometrical solution yields :

$$R_1 = \frac{A + R\left(1 - \cos(\alpha - \beta) + \sin(\alpha - \beta)\tan\gamma\right)}{\dfrac{1}{\cos\gamma} + \sin(\alpha - \beta)\tan\gamma - \cos(\alpha - \beta)};$$

$$C'D = R_1 \tan\gamma + \frac{(R_1 - R)\sin(\alpha - \beta)}{\cos\gamma}$$

Using the versines diagram, we find :

$$x = \frac{L^2 + 2RA + 2RL\gamma}{L + R\gamma}, \quad y = \frac{R(2A + \gamma L)}{L + R\gamma} = \frac{2A + \gamma L}{\alpha - \beta + \gamma}.$$

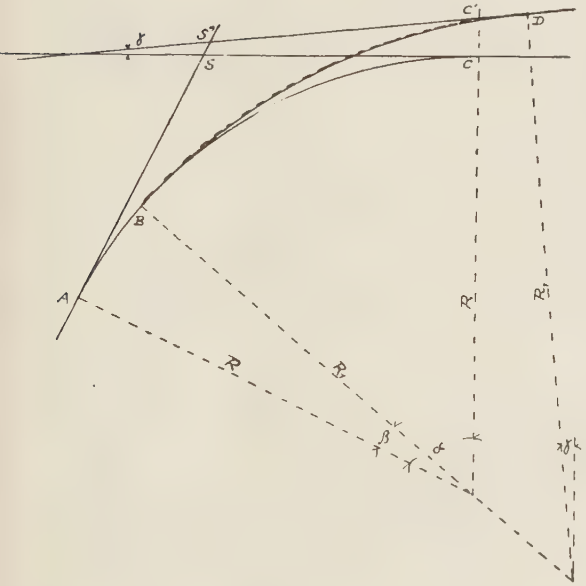

Fig. 6.

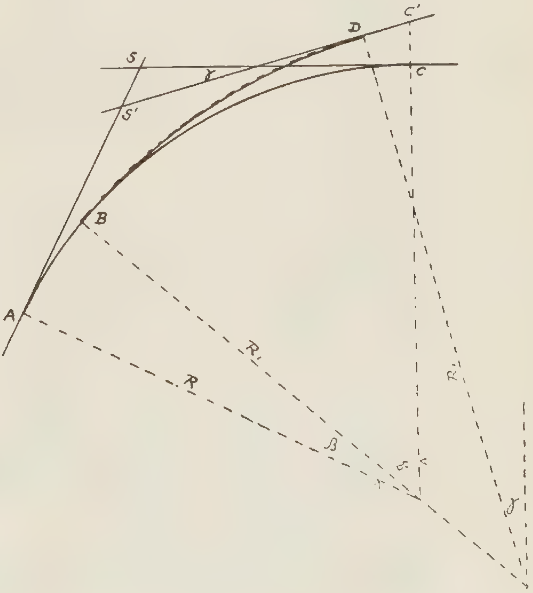

Fig. 7.

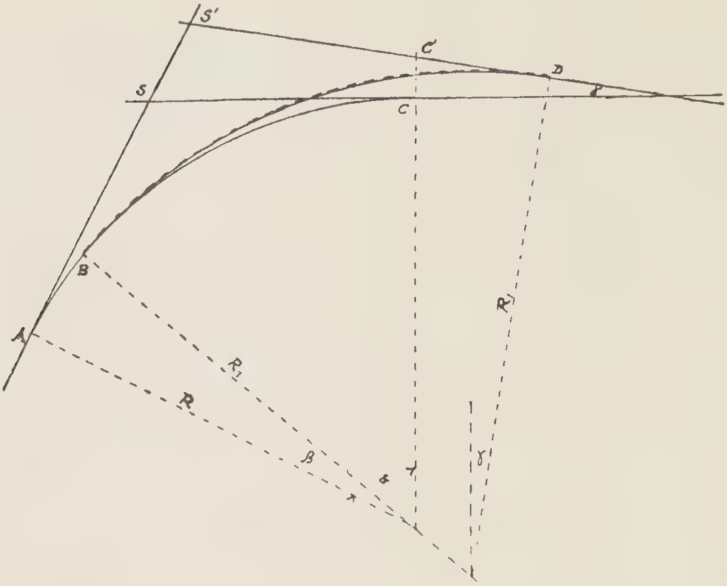

Fig. 8.

It is not always obvious at first which case applies in a particular instance. To distinguish the case of fig. 4 from that of fig. 5, or the case of fig. 6 from that of fig. 7, it is sufficient to calculate y by means of the formula corresponding to each case; the suitable formula yields a positive value for y.

At point B where the radius of the curve BD is equal to R_1, it should be verified that the difference between the versines f_{R_1} and f_R does not exceed the value ascertained from the formula $f_{R_1} - f_R = \frac{8.6}{v^2}$ (1), v being the speed in metres per second.

When $f_{R_1} - f_R > \frac{8.6}{v^2}$, a slight adjustment to the versines of the approach transition is sufficient to restore the progression of the curvature.

We will conclude by considering two cases of curve adjustment involving reverse curves.

Let TABC, in fig. 9, be an alignment which it is desired to replace by the cir-

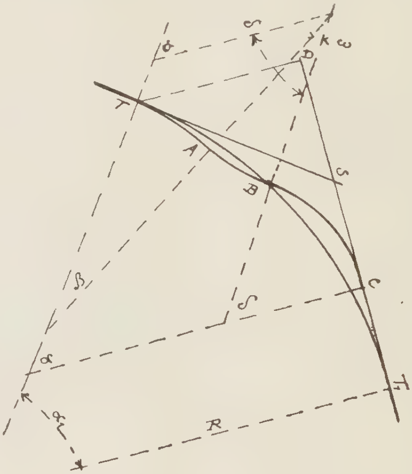

Fig. 9.

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(1) See the work quoted previously, in the footnote, page 331.

cular arc TT_1, of radius R, tangential to the straight line ST at T, and with the straight line ST_1 at T_1. The alignment TABC is made up of two curves, TA and BC, of the same hand, joined by the curve AB of the opposite hand.

Curve TA is tangential at T to the straight line ST, while curve BC is tangential at C to the straight line ST_1.

Considering the alignment TABC, we have :

$$TD = y_T = 2\,\Sigma\Sigma_C^T f,$$

f representing the versines of the curves CB, BA, AT, positive for the curves CB and AT, negative for the curve AB.

Considering the circular arc TT_1, of radius R, we have :

$$TD = y_T = \frac{x^2}{2\,R}, \quad \widehat{TT_1} = x,$$

whence :

$$2\,\Sigma\Sigma_C^T f = \frac{x^2}{2\,R}. \quad (1)$$

The central angle α of the alignment TABC is equal to the angle α_1 of the alignment TT_1.

$$\text{But } \alpha = \beta + \delta - \omega, \quad \alpha_1 = \frac{x}{R},$$

whence

$$\frac{x}{R} = \beta + \delta - \omega.$$

$$\frac{1}{R} = \frac{\beta + \delta - \omega}{x}, \quad R = \frac{x}{\beta + \delta - \omega},$$

and

$$2\,\Sigma\Sigma_C^T f = \frac{x^2}{2}\left(\frac{\beta + \delta - \omega}{x}\right) = \frac{x(\beta + \delta - \omega)}{2},$$

$$x = \frac{4\,\Sigma\Sigma_C^T f}{\beta + \delta - \omega}, \quad R = \frac{4\,\Sigma\Sigma_C^T f}{(\beta + \delta - \omega)^2},$$

$$\beta = \frac{2\,\Sigma_T^A f}{a}, \quad \delta = \frac{2\,\Sigma_B^C f}{a}, \quad \omega = \frac{2\,\Sigma_A^B f}{a},$$

a = chord length between two pegs.

In the table of throws, the versines-sum for the alignment TABC should equal the versines-sum for the arc TT_1, the versines of the curve AB being taken as negative.

Referring to fig. 10, imagine the same alignment as in fig. 9 to be replaced by the circular arc TT_1, of radius R, tangential one end at T to the straight line ST, and at the other end at T_1 to the straight line S_1T_1, which makes an angle γ with the straight line ST.

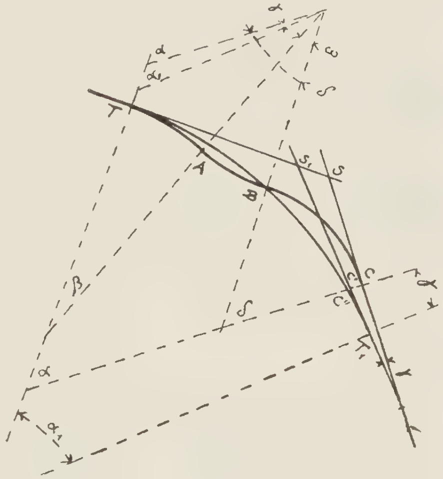

Fig. 10.

Considering the alignment TABC, the ordinate of point C with respect to the straight line TS produced is equal to :

$$y_C = \Sigma\Sigma_T^C f;$$

the versines of the arc AB being negative, the ordinate of point C" on the circular arc TT_1, of radius R, with respect to the same axis of the abscissæ, is equal to :

---

(1) When the straight line SC is shifted parallel to itself by an amount A, we have : $2\,\Sigma\Sigma_C^T f = \frac{x^2}{2\,R} \pm A$, according to the direction of the shift.

$$y_{c''} = \frac{(x - y)^2}{2\,R}, \quad x = \widehat{TT_1}, \quad y = T_1\,C',$$

$$C'C'' = \frac{y^2}{2\,R}.$$

Consequently :

$$CC' = CC'' - C'C'' =$$

$$= A - \frac{(x - y)^2}{2\,R} - 2\,\Sigma\Sigma^C f - \frac{y^2}{2\,R};$$

A is part of the data, so that :

$$x^2 + y^2 - 2\,xy - 4\,R\,\Sigma\Sigma_T^C f - y^2 = 2\,RA,$$

$$y \approx x - L,$$

L being the length of the alignment TABC.

The central angle α_1 of the circle TT_1 is equal to the central angle α of the alignment TABC reduced by the angle between the two tangents SC and S_1T_1;

$$\alpha_1 = \alpha - \gamma = \frac{x}{R}, \quad R = \frac{x}{\alpha - \gamma},$$

and :

$$x^2 - 2x\,(x - L) - 4\,\frac{x}{\alpha - \gamma}\,\Sigma\Sigma_T^C f =$$

$$= 2\,\frac{x}{\alpha - \gamma}\,A - x^2 + 2x\,L - \frac{4\,x\,\Sigma\Sigma_T^C f}{\alpha - \gamma} =$$

$$= \frac{2x\,A}{\alpha - \gamma},$$

$$x = 2\,L - \frac{4\Sigma\Sigma_T^C f + 2\,A}{\alpha - \gamma},$$

$$y = L - \frac{4\,\Sigma\Sigma_T^C f + 2\,A}{\alpha - \gamma},$$

$$\alpha = \beta + \delta - \omega, \quad \beta = \frac{2\,\Sigma_T^A f}{a},$$

$$\delta = \frac{2\,\Sigma_B^C f}{a}, \quad \omega = \frac{2\,\Sigma_A^B f}{a}.$$

We could also proceed by calculating, as we did previously, the ordinate of point T, with respect to the straight line SC produced, and the straight line S_1T_1 produced, respectively.

In the table of throws the difference between the versines-sum for the alignment TABC and the versines-sum for the arc TT_1, should equal :

$$\frac{\gamma\,a}{2} = \frac{10\,\gamma}{2}$$

for a chord length of 10.00 m.

The treatment of parabolic transition curves, without calculus (1), and the problems we have just solved, show that we applied a general method of calculation, the fundamental rules of which we will now summarise.

This method consists in superimposing the versines diagram or the curvatures diagram of the required alignment, upon the versines or curvatures diagram of the existing alignment, so as to be able to calculate the throw of each peg in the original alignment, required to bring it into the new alignment, some of the throws being conditioned by the particular circumstances of the problem.

The properties of the versines- or curvatures diagram of the new alignment are determined by the relations which exist, on the one hand, between the central angles of the two alignments, and on the other hand, between the ordinates of certains corresponding points of the two alignments; for example the difference between two of these ordinates may have to equal a certain distance, depending upon the topographical data of the scheme.

This method is a generalisation of that used in the realignment of curves, and therefore shares the same advantages, namely speed, simplicity, and considerable accuracy.

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(1) Work already quoted.

[621. 131.3 (.44) & 621. 132.3 (44).

P.L.M. "Pacific" locomotives, classes 231-G, 231-H and 231-K.

Trials carried out and results obtained,

by A. PARMANTIER,
Chief mechanical engineer, French National Railways, Northern Region.

(Revue Générale des Chemins de fer.)

The increased power of locomotives has been necessitated, as is known, largely by the introduction of metal coaches into the stock of the various railway companies — these coaches being incomparably stronger than wooden coaches, but at the same time a little heavier — whilst a further cause was the necessity for competing with road motor transport, by increasing the average speed of trains.

As there could be no suggestion of the demands being met entirely by the construction of new express locomotives, the required increase in effective power of the existing engines could only be obtained by increasing at the same time the efficiency and the maximum actual power.

In spite of numerous variations in the form, practically the same means have been used by all railways to attain this end: — increases in boiler pressures and superheat temperatures — use of feed water heaters — reduced wire-drawing in steam passages and reduced back pressure in the blast — improved draught and combustion.

The *Revue Générale des Chemins de Fer* has already given several examples of the investigations carried out, and the results obtained, by the Paris-Orléans (1), Est (2) and the State Railways (3).

From the following note it will be seen that the P.L.M., in endeavouring to improve their express locomotives, have followed the same principles, at the same time retaining the simplest and most conventional arrangements of the various parts, particularly the valve gear. The same desire for simplicity led the P.L.M. some time ago to replace the independent high and low pressure valve gears which are fitted to almost all other compound locomotives, by conjugated valve gears in which the ratio of the high pressure cylinder cut-off to the low-pressure cylinder cut-off remains fixed.

At the end of the note dealing with the successive changes which have taken place in the 4-6-2 engines, Mr. Parmantier questions whether independent valve gear, in spite of its complications, would not be preferable to conjugated valve gear, and if to facilitate starting, it would not be advantageous to complete this alteration by the provision of a device for working the high- and low-pressure cylinders under simple expansion.

Trials being carried out will show whether efficiency must be sacrified for simplicity or if, on the other hand, the gain to be expected from it would justify the suggested alteration and resultant complication of construction and later on of maintenance.

⁂

See *Revue Générale des Chemins de fer* :

(1) Mr. CHAPELON, July, 1931; Febr. and March, 1935.

(2) Messrs. PONCET and LEGUILLE, January, 1937.

(3) Mr. BARRIER, March, 1938.

The Paris-Lyon-Méditerranée (P.L.M.) Company has, during recent years, made various improvements in its *Pacific* locomotives and has perfected three new types of engine : the 231-G, 231-H and 231-K. This article deals with the alterations made, the trials carried out and the results obtained.

I. HISTORY.

The introduction of *Pacific* locomotives on the P. L. M. dates from 1909. This was the period when superheating was making its appearance and, according to its sponsors, was about to supplant compounding. The P. L. M. wished to compare the two ways of using the steam, and two *Pacific* prototypes were constructed, having a grate area of 4.25 m² (45.2 sq. ft.) and coupled wheels 2 m. (6 ft. 6 3/4 in.) in diameter :

— one four-cylinder compound locomotive, No. 6001 (1), using saturated steam :

boiler pressure 16 kgr./cm² (228 lb. per sq. in.);

total volume of the two low-pressure cylinders :

196 × 2 = 392 litres (23 920 cu. in.)

— one four cylinder simple expansion locomotive, No. 6101 (2), using superheated steam :

boiler pressure 12 kgr./cm² (171 lb. per sq. in.);

total volume of the four cylinders :

117 × 4 = 468 litres (28 560 cu. in.).

It was found that the superheated four-cylinder simple expansion engine was more efficient than the compound engine using saturated steam, and the Company adopted the former arrangement in the construction of a number of engines, one class, 6101-6171, having a boiler pressure of 12 kgr./cm² (171 lb. per sq. in), and another series (6172-6191) having a boiler pressure of 14 kgr./cm² (199 lb. per sq. in.).

One question however remained unsolved, that was, the choice, when using superheated steam, between simple expansion and compounding.

In 1912, therefore, a new type of *Pacific* locomotive, class 6200, superheated and compound, with a boiler pressure similar to 6001, of 16 kgr./cm² (228 lb. per sq. in.), but with larger cylinders — the total volume of the low-pressure cylinders being 215.5 × 2 = 431 litres (26 300 cu. in.), was put into service. This proved to be superior to the two original types, and it was decided to adopt it as the standard *Pacific* locomotive for the P. L. M. At the same time, it was decided to apply superheating to the original 6001, compound, type.

Trials carried out at this period with the converted 6001 locomotive gave the following specific results :

On the 6th February, 1913, a train of 487 t. (479.3 Engl. tons) was hauled from Laroche to Blaisy, 133 km. (82.6 miles) on a continuous average gradient of 1 in 416, and of 1 in 125 on the last 13 km. (8 miles), in 85 2/3 minutes, i.e. at an average speed of 93 km. (57.8 miles)an hour. The engine developed an average cylinder horse-power of 1885, and an average tender drawbar horsepower of 1274. The average consumptions per drawbar horse-power were 1.63 kgr. (3.59 lb.) of coal and 12.45 litres (2.74 Br. gall.) of water.

The compound locomotives, series No. 6200, following the general practice adopted by the P.L.M. for all compound locomotives constructed after 1899, when the 220-A (formerly C. 61-180) class were put into service, were fitted with a complete Walschaerts valve gear to each cylinder, but were given a definitely fixed cut-off (63 %) for the low-pressure cylinders (1).

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(1) See « The P. L. M. Company at the Ghent Exhibition, 1913 ». Published by the P. L. M.); *Le Génie Civil*, 24th May, 1913, page 67; and *La Technique Moderne*. 1st November, 1913, page 310.

(2) See « The P. L. M. Company at the Turin Exhibition, 1911. (Published by the P. L. M.)

When in 1922 it was found that the stock of express locomotives was insufficient, a new series of compound *Pacific* locomotives was constructed, class 6 300 — later classed 231-D — which differed from the 6 200 class only in the method of conjugating the valve gears. With a view to simplifying the interior mechanism, an endeavour was made to transmit the movement of the outside slide valve to the inside slide valve, and a type of conjugated valve gear was finally adopted and has since been fitted on all the P. L. M. Company's compound engines (2).

On the 231-D type Pacific locomotives the relation between the high and low-pressure valve gears is as follows :

Cut-off %	HP.	LP.
	40	52
	45	57
	50	63
	55	68
	60	72

Comparative trials carried out with superheated locomotives, compound and simple expansion, showed a marked advantage in favour of the compound engine, and the P. L. M. decided to proceed with the conversion of all their simple expansion *Pacific* locomotives to compound (3).

The characteristics of the P. L. M. *Pacific* locomotives, on the completion of these alterations in 1930, are summed up in Table 1 hereafter.

Table 1.

Class of locomotive.		Diameter of driving wheels.	Grate area.	Boiler pressure.	Total volume of 2 cylinders.		Ratio. $\frac{V_{LP}}{V_{HP}}$	Type of valve gear.
New description.	Old description.				HP.	LP.		
				kgr./cm² *(lb./sq.in.)*	litres *(cu. in.)*	litres *(cu. in.)*		
231-B.	6172-6191	2.000 m. *(6' 6 3/4")*	4.25 m² *(45.2 sq. ft.)*	14 *(199)*	225 *(13 730)*	431 *(26 300)*	1.91	Conjugated valve gear.
231-C-1	Prototype 6001.			16 *(228)*	180 *(10 980)*	392 *(23 920)*	2.18	Separate valve gear but with the low pressure cut-off fixed at 63 %.
231-C-2 to 86.	Class 6200			16 *(228)*	197 *(12 020)*	431 *(26 300)*	2.18	
231-D.	Class 6300			16 *(228)*	197 *(12 020)*	431 *(26 300)*	2.18	Conjugated valve gear.
231-E.	231-A (former 6101-6171, converted)			12 *(171)*	265 *(16 170)*	431 *(26 300)*	1.62	Conjugated valve gear.

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(1) The report of Mr. E. CHABAL to the International Congress of Applied Mechanics, 1900 (second question — Locomotive trials carried out by the P. L. M. Company) gives the reasons which led the P. L. M. to adopt a fixed cut-off of 63 % for low-pressure cylinders (page 215 of the proceedings; Dunod, Publisher). Release type reversing gear, of the type described in the *Revue Générale des Chemins de fer*, September 1898 (page 193), was fitted.

(2) This type of conjugated valve gear was described by Mr. VALLANTIN in his note on the 4-8-2 *Mountain* locomotives of the P. L. M. Company, in the *Revue Générale des Chemins de fer*, February 1926, page 92.

(3) See communication by Mr. VALLANTIN, to the « Institute of Locomotive Engineers », 26th February 1931. — *Revue Générale des Chemins de fer*, April 1931, page 428.

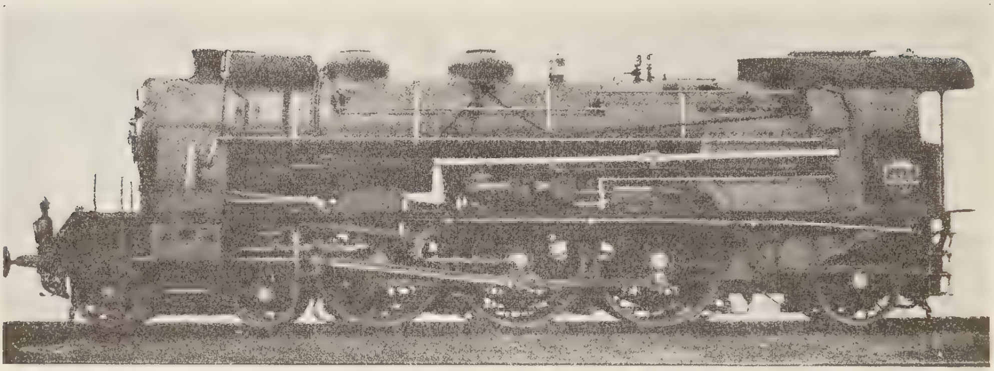

Fig. 1. — 231-D locomotive before application of smoke deflectors.

II. 231-D LOCOMOTIVES.

The 231-D class superheated compound *Pacific* locomotives, with a boiler pressure of 16 kgr./cm² (228 lb. per sq. in.), conjugated valve gear, piston valves and single clover-leaf type blast pipe, have been, from 1922 until recent years, the type of locomotive used by the P. L. M. for express trains (figs. 1, 2, and 3).

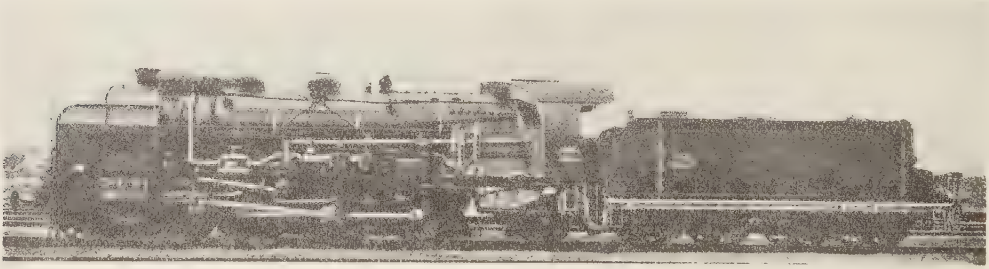

Fig. 2. — 231-D locomotive fitted up for tests.

A. — Improvements effected in the 231-D locomotives.

Various improvements were progressively applied to the 231-D engines : the fitting of a feed water heater, improved superheat, application of smoke deflector screens.

We shall briefly review the modifications carried out :

1. *Feed water preheating by exhaust steam from the cylinders.* — Trials carried out since 1921 on various classes of locomotives had shewn the advantages accruing from feed water heating by exhaust steam from the cylinders, and led to the adoption of feed water heaters, with condensation of the water by mixing (1).

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(1) See *Revue Générale des Chemins de fer*, February 1925, page 114, Note by Mr. PARMANTIER.

The P. L. M. Pacifics are all equipped at the present time with ACFI feed water heaters, R. M. type.

2. *Improved superheating.* — Investigations undertaken in 1925 with a view to improving the obviously insufficient superheating of a class of simple expansion goods locomotive showed the possibility of obtaining favourable results by suitably distributing the combustion gases between the superheater tubes and the boiler tubes (¹).

Consequent upon the information gained in this direction, various modifications were applied to the 231-D locomotives, which allowed the superheat temperature to be increased from 260° to 380° C. (500 to 716° F.) an increase of 120° C. (216° F.) which resulted in a fuel economy of more than 10 %.

The modifications were as follows :

— reduction in the diameter the tubes are fitted in the firebox tube plate : 41 mm. (1 5/8 in.) instead of 50 mm. (2 in.);

— smaller diameter of superheater elements [replacement of the 31 × 38 mm. (1 1/4" × 1 1/2") diameter tubes by 28 × 35 mm. (1 1/8" × 1 3/8") diameter tubes].

— improved form of supports and stays (use of thin plate supports giving a greatly reduced section);

— increased diameter of the large superheater tubes [replacement of 125 × × 133 mm. (4 29/32" × 5 1/4") diameter tubes by 135 × 143 mm. (5 5/16" × 5 19/32") diameter tubes];

— superheater elements lengthened towards the back (distance of the back spearheads from the firebox tube plate reduced from 690 to 450 mm. (27 1/8 in. to 17 11/16 in.).

Tables 2 and 3 sum up the characteristics of the boiler before and after alterations.

3. *Tentative improvements in blast pipe arrangement and use of smoke deflectors.* — As far back as 1925, various tests have been carried out with a view to improving the variable clover leaf pattern blast pipe fitted on the 231-D engines.

Experiments were carried out with large section exhaust arrangements, nozzles and chimneys of large diameter with mobile parts of various shapes (amongst them a four-ported crossbar type) and sometimes with petticoats. The favourable results which were obtained could not, however, be usefully applied as the decreased counterpressure, which was one of the results aimed at, had the effect of lowering the throw of the smoke to a most undesirable degree.

It was not until 1930 when smoke deflectors appeared that the study of improved blast pipe design on the 231-D was taken up again, and this was the start of the conversion of the P. L. M. Pacific engines to 231-G, 231-H and 231-K classes.

The smoke deflectors, on account of the undoubtedly increased safety which they provide, were fitted from the start to all P. L. M. *Pacific* engines, including the 231-D class.

B. — **Results of trials.**

A 231-D locomotive, to which all the modifications mentioned had been applied, was subjected to constant-speed trials on the line.

The *results obtained* are summarised below :

(a) Power of the locomotive (figures 4 and 5).

The maximum power, defined as the sustained tractive effort over 100 km.

(¹) See *Revue Générale des Chemins de fer*, June 1929, page 426; Note by Mr. Bourrié.

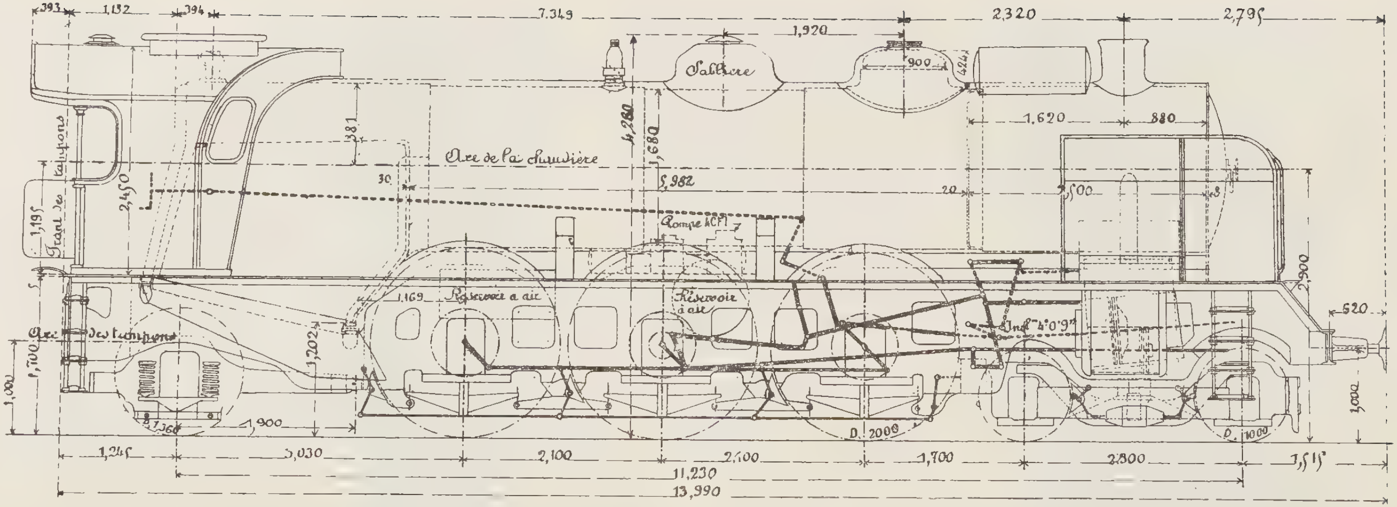

Fig. 3. — Diagram of 231-D locomotives.

Grate :

Full length		2.125 m. (*6' 11 43/64"*)
Width	front	2.086 m. (*6' 10 1/8"*)
	rear	1.922 m. (*6' 3 43/64"*)
Area		4.25 m² (*45.2 sq. ft.*)

Outside firebox :

Height of crown sheet above foundation ring	front	1.9952 m. (*6' 6 9/16"*)
	rear	1.4807 m. (*4' 10 5/16"*)
Inside length	top	2.283 m. (*7' 5 7/8"*)
	bottom	2.078 m. (*6' 9 13/16"*)
Inside width	along boiler centre line	1.516 m. (*4' 11 43/64"*)
	bottom front	2.086 m. (*6' 10 1/8"*)
	bottom rear	1.922 m. (*6' 3 5/16"*)
Thickness of copper	side walls	0.014 m. (*9/16"*)
	back plate	0.014 m. (*9/16"*)
Thickness of copper tube plate	at the tubes	0.030 m. (*1 3/16"*)
	at the bottom	0.014 m. (*9/16"*)

Tubes :

Number (smooth steel tubes)	Tubes of 0.055 m. (*2 3/16"*) outside diam.	128
	Tubes of 0.143 m. (*5 19/32"*) outside diam.	26

Crank pins :

		Diam.	Length.	Centre to centre.
Connecting rod big ends	Hp.	0.130 m. (*5 1/8"*)	0.172 m. (*6 25/32"*)	2.230 m. (*7' 3 51/64"*)
	Lp.	0.220 m. (*8 11/16"*)	0.130 m. (*5 1/8"*)	0.690 m. (*2' 3 1/8"*)
Coupling rods	3rd pair of wheels	0.105 m. (*4 1/8"*)	0.090 m. (*3 35/64"*)	1.910 m. (*6' 3 13/64"*)
	4th pair of wheels	0.180 m. (*7 3/32"*)	0.095 m. (*3 47/64"*)	1.885 m. (*6' 2 13/64"*)
	5th pair of wheels	0.105 m. (*4 1/8"*)	0.090 m. (*3 35/64"*)	1.885 m. (*6' 2 13/64"*)

Lateral play on each side of engine :

Bogie	Pivot	0.060 m. (*2 3/8"*)
	Axles	0.001 m. (*0.039"*)
3rd and 5th axles		0.001 m. (0.039")
4th axle	Tyres thinned down by	0.010 m. (*3 15/16"*)
	Axle	0.001 m. (*0.039"*)
Bissel truck	Pivot	0.066 m. (*2 5/8"*)
	Axle	0.001 m. (*0.039"*)

Springs :

1st and second pairs of wheels : 15 plates, 120 × 15 mm. (*4 3/4" × 19/32"*)	chord	1.245 m. (*4' 1"*)
	camber	0.045 m. (*1 49/64"*)

Thickness	0.055-m. tubes	0.002 m. (*5/64"*)
	0.143-m. tubes	0.004 m. (*5/32"*)
Distance between tube plates		5.982 m. (*19' 7 1/2"*)

Heating surface :

Firebox	15.68 m² (*168.8 sq. ft.*)
Tubes (inside area)	190.54 m² (*2 050 sq. ft.*)
Total	206.22 m² (*2 220 sq. ft.*)

Superheater :

Number of elements	26
Outside diam. of tubes	0.035 m. (*1 3/8"*)
Superheating surface	68.29 m² (*735 sq. ft.*)

Boiler :

Outside length of outside firebox	top	2.543 m. (*8' 4 1/8"*)
	bottom	2.309 m. (*7' 6 29/32"*)
Outside width of outside firebox	front	2.3415 m. (*7' 8 5/32"*)
	rear	2.181 m. (*7' 1 7/8"*)
Inside diameter of large barrel ring		1.680 m. (*5' 6 5/32"*)
Length of barrel		5.899 m. (*19' 4 1/4"*)
Thickness of barrel plates		0.019 m. (*3/4"*)
Distance between rail top and bottom of foundation ring		1.202 m. (*3' 11 5/16"*)
Inside length of smokebox		2.500 m. (*8' 2 7/16"*)
Inside diameter of smokebox		1.718 m. (*5' 7 5/8"*)
Total boiler capacity		11.740 m³ (*414.6 cu. ft.*)
Water capacity of boiler		8.360 m³ (*29.5 cu. ft.*)
Normal water level above firebox crown, front		0.114 m. (*4 1/2"*)
Boiler pressure		16 kgr./cm² (*228 lb./sq. in.*)
Diameter of safety valves		0.106 m. (*4 5/32"*)
Inside diameter of chimney	top	0.436 m. (*17 5/32"*)
	bottom	0.356 m. (*14"*)
Distance between feedwater couplings centres.		0.840 m. (*2' 9 1/16"*)

Frame :

Distance between main frames	1.234 m. (*4' 0 19/32"*)
Thickness of main frames	0.028 m. (*1 1/8"*)
Distance between handrail post centres	2.600 m. (*8' 6 23/64"*)

Wheels and axles :

Wheel diameter, reckoned with 70-mm. (2 3/4") tyres	1st and 2nd pairs	1.000 m. (*3' 3 3/8"*)
	3rd, 4th, and 5th pairs.	2.000 m. (*6' 6 3/4"*)
	6th pair	1.360 m. (*4' 5 35/64"*)
Distance between tyres (inside)		1.360 m. (*4' 5 35/64"*)

		Diam.	Length	From centre to centre
Journals	1st and 2nd axles	0.170 m. (*6 11/16"*)	0.270 m. (*10 5/8"*)	1.090 m. (*3' 7"*)
	3rd axle	0.220 m. (*8 11/16"*)	0.230 m. (*9 1/16"*)	1.240 m. (*4' 0 53/64"*)
	4th and 5th axles	0.220 m. (*8 11/16"*)	0.250 m. (*9 7/8"*)	1.150 m. (*3' 9 9/32"*)
	6th axle	0.200 m. (*7 7/8"*)	0.280 m. (*11 1/32"*)	1.120 m. (*3' 8 5/64"*)

3rd, 4th and 5th pairs of wheels : 16 plates, 110 × 12 mm. (*4 3/8" × 15/32"*)	chord		1.0878 m. (*3' 6 53/64"*)
	camber		0.070 m. (*2 3/4"*)
6th pair of wheels	Helical, cylindrical, 6 1/4 turns	Aver. diam. of coil.	0.155 m. (*6 1/8"*)
		Aver. diam. of wire.	0.037 m. (*1 29/64"*)
		Free height	0.3652 m. (*14 11/32"*)

Motion :

		HP.	LP.
Cylinder diameter		0.440 m. (*17 5/16"*)	0.650 m. (*25 5/8"*)
Piston stroke		0.650 m. (*25 5/8"*)	0.650 m. (*25 5/8"*)
Length of connecting rods		3.000 m. (*9' 10 1/8"*)	1.675 m. (*5' 6"*)
Distance between centre lines of	cylinders	2.230 m. (*7' 3 25/32"*)	0.690 m. (*2' 3 1/8"*)
	valves rods	2.280 m. (*7' 5 3/4"*)	0.705 m. (*2' 3 3/4"*)
Distance between centre lines of links		2.465 m. (*8' 1"*)	—
Inclination of cylinders		0°	4° 0' 9"

The driving cranks for the high pressure cylinders form an angle of 175° 59' 51" with the driving cranks of the low-pressure cylinders.

Valve gear :

	HP.	LP.
Type of valve gear	Walschaerts.	Conjugated.
Type of valves	Piston.	Piston.
Piston valve diameter	0.240 m. (*9 7/16"*)	0.360 m. (*14 3/16"*)
Radius of eccentricity	0.160 m. (*6 5/16"*)	0.2215 m. (*8 23/32"*)
Max. stroke of piston valves	0.172 m. (*6 25/32"*)	—
Steam lap (inside)	0.034 m. (*1 11/32"*)	0.034 m. (*1 11/32"*)
Exhaust lap (outside)	—0.004 m. (*—5/32"*)	0.008 m. (*3/16"*)
Max. cut-off in full gear	79.75 %	87.45 %
Admission ports	0.578 m. × 0.040 m. (*22 3/4" × 1 9/16"*)	0.891 m. × 0.050 m. (*35" × 1 35/32"*)
Volume of receiver		0.382 m³ (*13.5 cu. ft.*)

On each side of the locomotive a single valve motion operates the high-pressure piston valve directly, and the low-pressure cylinder valve-gear through a countershaft and rocking lever.

Weight :

		Kgr.	*Lb.*
Empty engine (tyres half-worn)		87 320	*192 500*
Hot water at normal level		7 740	*17 060*
Coal assumed to be in firebox		1 300	*2 870*
Sand (sandbox half full)		150	*330*
Locomotive in average working order	1st pair of wheels	11 900	*26 230*
	2nd pair of wheels	11 900	*26 230*
	3rd pair of wheels	18 500	*40 790*
	4th pair of wheels	18 500	*40 790*
	5th pair of wheels	18 500	*40 790*
	6th pair of wheels	17 210	*37 940*
	Total	96 510	*212 770*

These engines are equipped for steam heating of trains.

Table 2.

Arrangement.	Boiler tubes 6 m. (19 ft. 8 1/4 in.) long.			Superheater tubes 6 m. (19 ft. 8 1/4 in.) long.			Superheater elements.			Total heating surface C.	Superheating surface Σ.
	Number.	Diameter.		Number.	Diameter.		Diameter.		Distance between back spearheads and tube plate.		
		Inside.	Outside.		Inside.	Outside.	Inside.	Outside.			
Initial . .	143	51 mm. *(2 1/64")*	55 mm. *(2 3/16")*	28	125 mm. *(4 29/32")*	133 mm. *(5 1/4")*	31 mm. *(1 1/4")*	38 mm. *(1 1/2")*	690 mm. *(27 1/8")*	220.2 m² *(2 370 sq.ft.)*	70.6 m² *(760 sq.ft.)*
Final. . .	128	51 mm. *(2 1/64")*	55 mm. *(2 3/16")*	26	135 mm. *(5 5/16")*	143 mm. *(5 19/32")*	28 mm. *(1 1/8")*	35 mm. *(1 3/8")*	450 mm. *(17 11/16")*	206 m² *(2 217 sq.ft.)*	68.3 m² *(735 sq.ft.)*

Table 3.

Arrangement.	Cross sectional area of gas passages		Resistance to passage of gases		Ratios.			Superheat temperature.
	through superheater tubes, *Ss*.	through boiler tubes, *Sb*.	of superheater tubes $Rs \times 10^{-4}$	of boiler tubes $Rb \times 10^{-4}$	$\frac{\Sigma}{C}$.	$\frac{Ss}{Sb}$.	$\frac{Rs}{Rb}$.	
Initial . . .	0.24 m² *(372 sq. in.)*	0.29 m² *(450 sq. in.)*	30	79	0.321	0.830	0.379	260° C. *(500° F.)*
Final	0.27 m² *(419 sq. in.)*	0.26 m² *(403 sq. in.)*	17	88	0.331	1.040	0.197	380° C. *(716° F.)*

(62 miles) an hour (1) was as shown in table 4 hereafter (2).

Table 4.

Hourly speed.	Cut-off HP, %.	Indicated horse-power.	Effective horse-power.
100 km. *(62 miles).*	45	2 067	1 567
120 km. *(75 miles)*	40	1 951	1 277

Indicator diagrams are shown in figure 6.

(b) Temperature of the steam (high pressure steam chests). — From 353° to 380° C. (667 to 716° F.) according to running conditions.

(c) Combustion and draught. — The combustion did not exceed 415 kgr./m^2 (85 lb. per sq. ft.) per hour. The corresponding draught was 130 mm. (5.12 in.) of water for 400 gr. (5.6 lb./sq. in.) of counterpressure in the cylinders.

(d) Evaporative power of the boiler. - - The calculated capacity for evaporation did not exceed 70 kgr./m^2 (14.3 lb. per sq. foot) per hour.

(e) Consumption and overall efficiency (see Table 5).

III. 231-G LOCOMOTIVES.

The 231-G locomotives (figs. 8 and 9) represent the first type of modern *Pacific* engine used by the P. L. M. They were directly derived from the 231-D, from which they differed essentially only by reason of the improvements made in the blast and in the low-pressure cylinders.

All the 231-D locomotives of the P.L.M. are to be progressively converted to 231-G class.

Table 5.

Hourly speed.	P_i	P_e	$\frac{P_e}{P_i}$.	Consumption per indicated horse-power/hour.		Consumption per effective horse-power/hour.		Overall efficiency	
				water.	coal.	water.	coal.	indicated.	effective.
	(H.P.)	(H.P.)		kgr. *(lb.)*	kgr. *(lb.)*	kgr. *(lb.)*	kgr. *(lb.)*		
100 km. *(62 miles)*	1 988	1 507	0.76	6.440 *(14.19)*	0.890 *(1.96)*	8.490 *(18.71)*	1.170 *(2.58)*	0.09	0.06
	2 150	1 600	0.74	6.170 *(13.60)*	0.860 *(1.89)*	8.300 *(18.29)*	1.150 *(2.53)*	0.09	0.07
120 km. *(75 miles)*	1 714	1 121	0.65	7.190 *(15.85)*	0.980 *(2.16)*	10.990 *(24.22)*	1.500 *(3.31)*	0.08	0.05
	2 000	1 300	0.65	6.910 *(15.22)*	0.970 *(2.14)*	10.630 *(23.43)*	1.490 *(3.28)*	0.08	0.05

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(1) 100 km. (62 miles) is the distance between Laroche and Laumes, whereon the constant-speed trials were carried out.

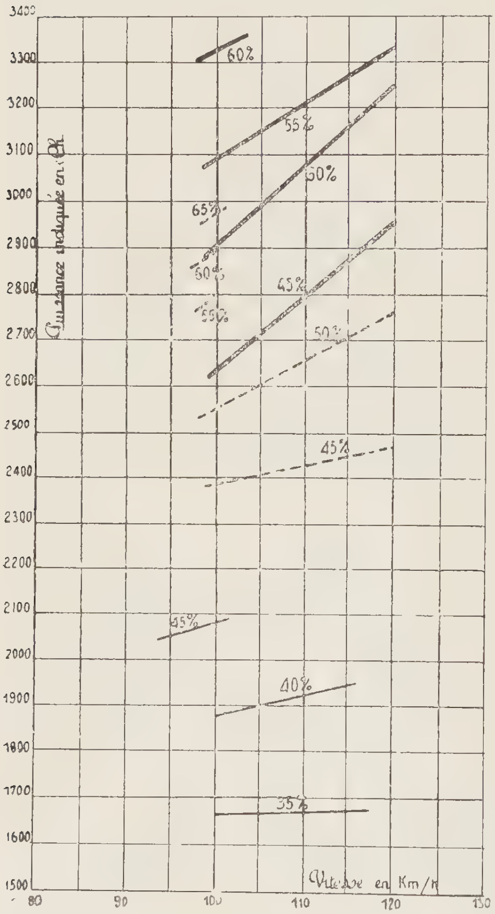
(2) It should be noted that the power absorbed to haul the original 231-D locomotive and its 30 m^3 (6 600 Br. gall.) tender was found to equal 500 H.P. at 100 km. (62 miles) an hour, and 700 H.P. at 120 km. (75 miles) an hour, whereas in all subsequent tests of the altered 231-D locomotives the power absorbed was about 600 H.P. at 100 km. an hour and 800 H.P. at 120 km. It appears likely that this anomaly is due to an indicator diagram error.

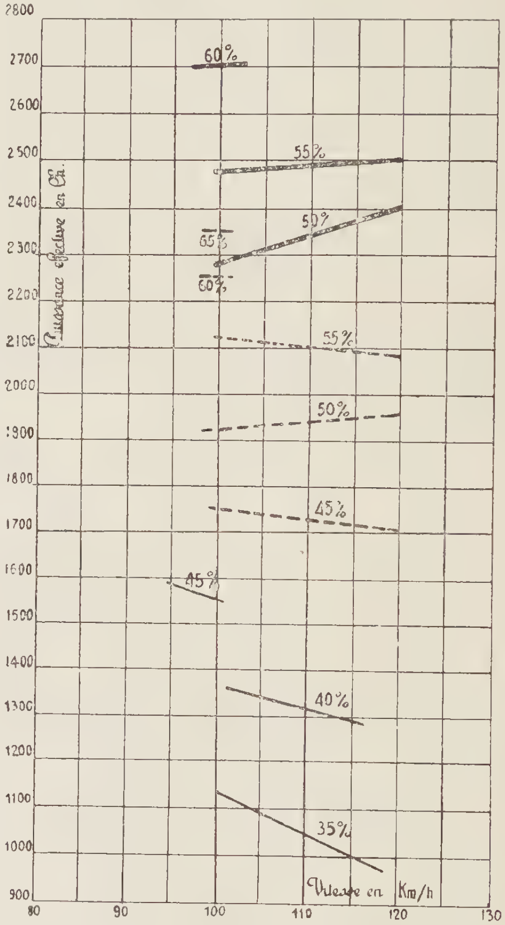
A. — Special modifications in the 231-G class.

1. *Improvements in blast pipe design.* — *(a)* Trials of enlarged single blast pipes.

Various devices were successively compared with the original clover-leaf pattern exhaust :

— large-diameter chimney and blast pipe;





Legend :

——— 231-D loc.

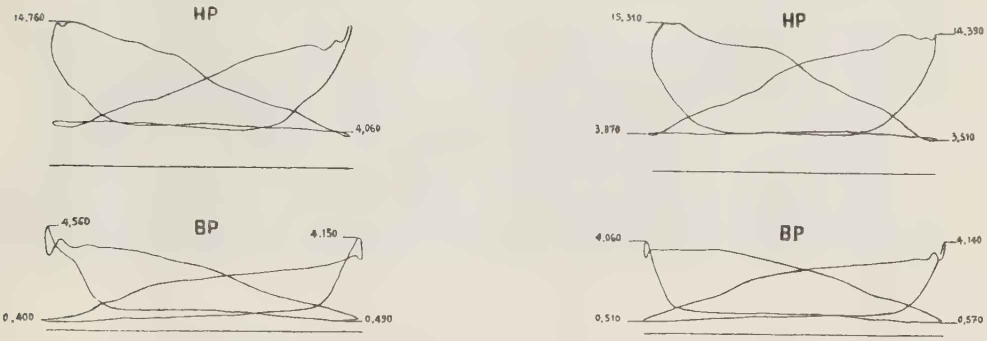
- - - - - 231-G loc.

━━━ 231-H loc.

Fig. 4. — Indicated horse-power of 231-D, 231-G and 231-H locomotives.

Fig. 5. — Horse-power at tender drawbar, on the level, of 231-D, 231-G and 231-H locomotives.

Note : Puissance indiquée en ch. = indicated horse-power. — Vitesse = speed.



Train of 19-5-32.
Hp cut-off 40 %, speed 120 km./h.

Train of 20-5-32
Hp cut-off 45 %, speed 100 km./h.

	Front face.	Rear face.	Total.
Horse-power, hp cyls.	583	639	1 222
Horse-power, lp cyls.	324	405	729
Total horse-power.			1 951

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.626$$

	Front face.	Rear face.	Total.
Horse-power, hp cyls.	592	643	1 235
Horse-power, lp cyls.	386	446	832
Total horse-power.			2 067

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.597$$

Fig. 6. — Indicator diagrams, 231-D locomotives.

— variable exhaust nozzles with three ports (clover leaf), four ports (crossbars), and six ports;

— exhausts without petticoats, with one, and with two petticoats;

The trials showed that a considerable improvement could be obtained by providing an exhaust with the following arrangements :

— large-section passages for steam and combustion gases;

— variable part made up of a four-ported nozzle so as to increase the area of contact between gases and steam;

— petticoat to even out the combustion of coal on the grate.

By using a chimney of 500 mm. (19 11/16 in.) diameter at the choke, instead of 356 mm. (14 in.), and a nozzle giving a steam passage section of 260—172 cm² (40.3—26.7 sq. in.) (1) instead of 181—120 cm² (28.1—18.6 sq. in.) as with the clover-leaf type, it has been found possible, for equal draught, to reduce by 50 % the counterpressure in the cylinders; in practice, a drop of 102 mm. (4 in.) in the smokebox was obtained, in place of 40 mm. (1.57 in.) with the original clover-leaf design (fig. 10); a slight increase in indicated and actual horse-power and a slight decrease in coal and water consumption were also noted.

Considerable improvement had therefore been made in blast pipe design. The solution adopted, however, gave an increased diameter of the exhaust pipe which presented the drawback of obstructing the smoke box transversely,

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(1) The two values show, firstly the section of the exhaust open, and secondly the section of the exhaust closed.

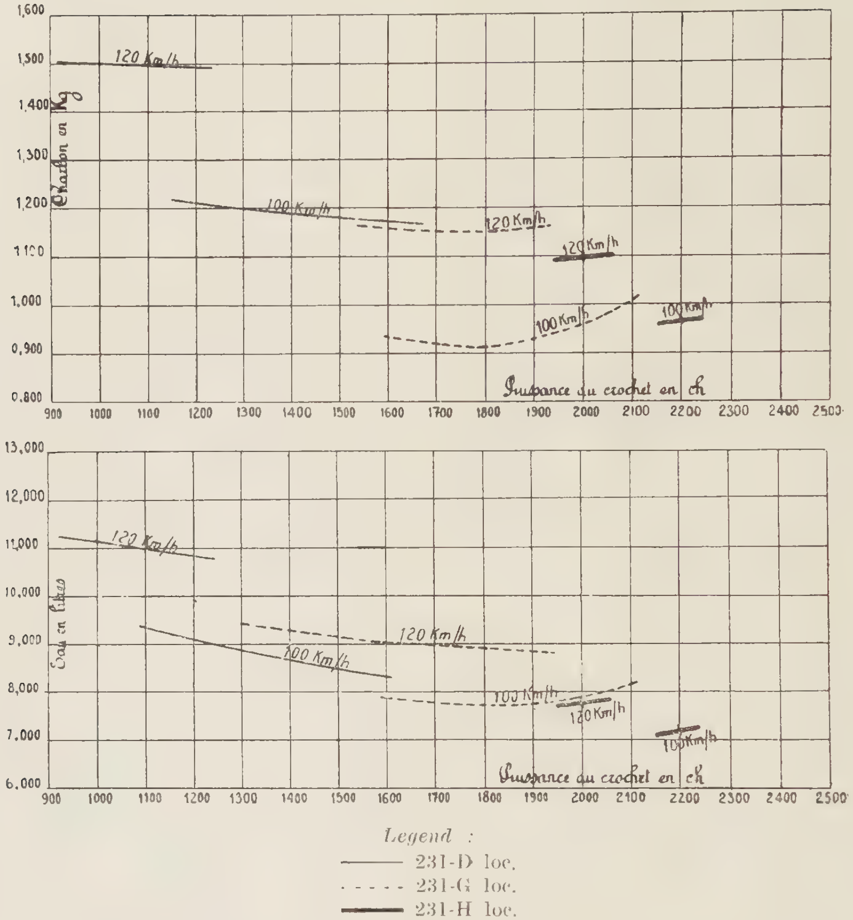

Fig. 7. — Coal and water consumption of 231-D, 231-G and 231-H locomotives (per tender D.B.H.P.-hour).

Note : Charbon, en kg. = coal, in kgr. — Eau, en litres = water, in litres. — Puissance au crochet en ch. = D. B. H. P.

and to obviate this the double blast pipe arrangement was adopted, an arrangement which allowed the passage areas to be increased, at the same time retaining the normal width of the exhaust pipes.

(b) Trials and adoption of the P.L.M. double blast pipe.

The splitting of the P. L. M. single exhaust was done without any difficulty and the P. L. M. double type exhaust, with crossbars and petticoats (fig. 11) was designed, the features of the arrangement being shown in fig. 12.

This type of exhaust has been adopted for all P. L. M. locomotives which are to be converted or modified.

On the 231-G locomotives, the chimneys have a diameter at the choke of

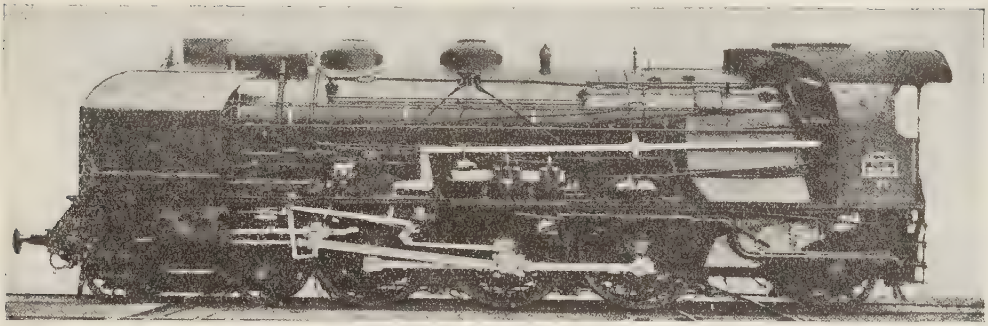

Fig. 8. — 231-G locomotive.

330 mm. (13 in.) and with 100 gr. (1.42 lb./sq. in.) counterpressure in the cylinders, the double blast pipe gives 120 mm. (4.72 in.) draught, or an increase of 18 % compared with the single blast pipe with enlarged chimney and 200 % compared with the original blast pipe (fig. 10).

2. *Enlarged steam passages in the low-pressure cylinders.* — At the time that attempts were being made to improve the exhaust, the design of the low-pressure cylinders was being modified so as to facilitate the passage of the steam. The steam passage was provided with a progressive section allowing all the ports to receive and pass the steam; the increase in the steam passage was about 10 %.

The new low-pressure cylinders gave an increased power which, in the case of a locomotive provided with single blast pipe and enlarged chimney (1) was about 100 H.P. at 100 km. (62 miles) an hour.

3. *Improved lubrication.* — The 231-G locomotives, being more powerful than the 231-D, work a heavier service and it has been found necessary to substitute the sight-feed lubricator of the 231-D by a mechanical lubricator on the 231-G.

The mechanical lubricator fitted to the 231-G engines is of the F. S. C. type with two chambers of 18 litres (4 Br. gall.) total capacity and 16 feeds;

— one chamber for superheater oil :
  four feeds to the high-pressure cylinders;
  four feeds to the high-pressure steam chests;
  two feeds to the low-pressure steam chests;

— one chamber for motion lubricating oil;
  six feeds for the bearings of the three driving axles.

4. *Superheater headers with separate chambers.* — Subsequently to the trials described below, it was decided to provide a steam collector with separate chambers, in place of the single header.

5. *Reduction in weight of piston val-*

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(1) Double blast pipes have not been tried on a *Pacific* locomotive fitted with the original type of cylinders, and it has not, therefore, been possible to give details of the advantages to be gained from using the new low-pressure cylinders on a locomotive fitted with the double blast pipe.

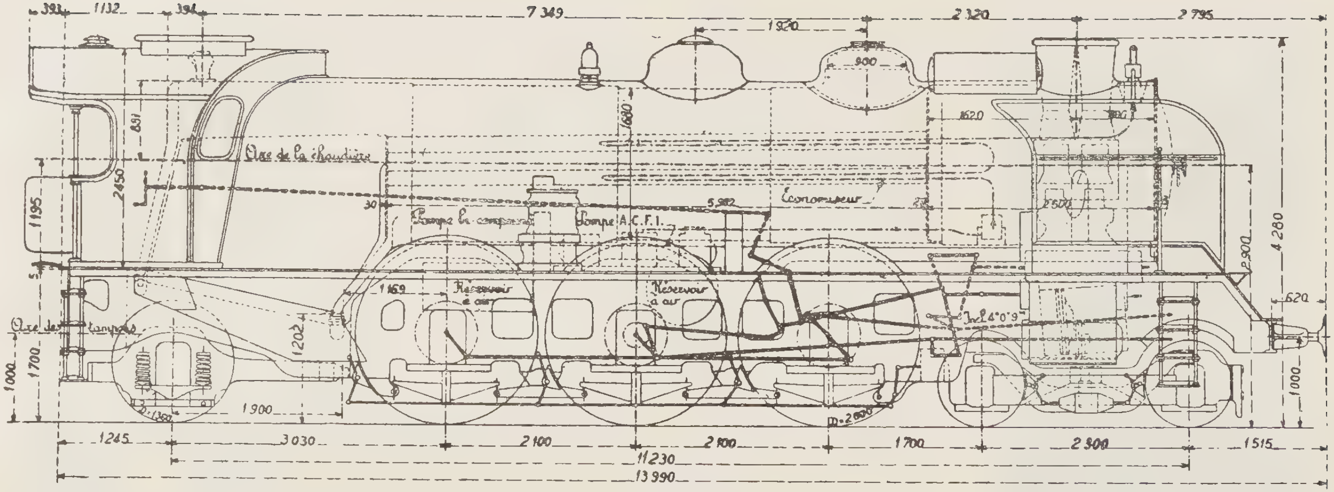


Fig. 9. — Diagram of 231-G locomotives.

Grate :

Full length		2.125 m. (*6' 11 43/64"*)
Width	front	2.086 m. (*6' 10 1/8"*)
	rear	1.922 m. (*6' 3 43/64"*)
Area		4.25 m² (*45.2 sq. ft.*)

Outside firebox :

Height of crown sheet above foundation ring	front		1.9952 m. (*6' 6 9/16"*)
	rear		1.4807 m. (*4' 10 5/16"*)
Inside length	top		2.283 m. (*7' 5 7/8"*)
	bottom		2.078 m. (*6' 9 13/16"*)
Inside width	along boiler centre line		1.516 m. (*4' 11 43/64"*)
	bottom	front	2.086 m. (*6' 10 1/8"*)
		rear	1.922 m. (*6' 3 5/16"*)
Thickness of copper	side walls		0.014 m. (*9/16"*)
	back plate		0.014 m. (*9/16"*)
Thickness of copper tube plate	at the tubes		0.030 m. (*1 3/16"*)
	at the bottom		0.014 m. (*1 3/16"*)

Tubes :

Number (smooth steel tubes)	Tubes of 0.055 m. (*2 3/16"*) outside diam.	128
	Tubes of 0.143 m. (*5 19/32"*) outside diam.	26

Crank pins :

		Diam.	Length.	Centre to centre.
Connecting rod big ends	Hp.	0.130 m. (*5 1/8"*)	0.172 m. (*6 25/32"*)	2.230 m. (*7' 3 51/64"*)
	Lp.	0.220 m. (*8 11/16"*)	0.130 m. (*5 1/8"*)	0.690 m. (*2' 3 1/8"*)
Coupling rods	3rd pair of wheels	0.105 m. (*4 1/8"*)	0.090 m. (*3 35/64"*)	1.910 m. (*6' 3 13/64"*)
	4th pair of wheels	0.180 m. (*7 3/32"*)	0.095 m. (*3 47/64"*)	1.885 m. (*6' 2 13/64"*)
	5th pair of wheels	0.105 m. (*4 1/8"*)	0.090 m. (*3 35/64"*)	1.885 m. (*6' 2 13/64"*)

Lateral play on each side of engine :

Bogie	Pivot	0.060 m. (*2 3/8"*)
	Axles	0.001 m. (*0.039"*)
3rd and 5th axles		0.001 m. (*0.039"*)
4th axle	Tyres thinned down	0.010 m. (*3 15/16"*)
	Axles	0.001 m. (*0.039"*)
Bissel truck	Pivot	0.056 m. (*2 13/64"*)
	Axle	0.001 m. (*0.039"*)

Springs :

1st and second pairs of wheels: 15 plates, 0.120 × 0.015 mm. (*4 3/4" × 19/32"*)	chord	1.245 m. (*4' 1"*)
	camber	0.045 m. (*1 49/64"*)

Thickness	0.055-m. tubes	0.002 m. *(5/64")*
	0.143-m. tubes	0.004 m. *(5/32")*
Distance between tube plates		5.982 m. *(19' 7 1/2")*

Heating surface :

Firebox	15.68 m² *(168.8 sq. ft.)*
Tubes (inside area)	190.54 m² *(2 050 sq. ft.)*
Total	206.22 m² *(2 220 sq. ft.)*

Superheater :

Number of elements	26
Outside diam. of tubes	0.035 m. *(1 3/8")*
Superheating surface	44.58 m² *(480 sq. ft.)*

Economiser (mixed type) with single collector and 6 take-offs :

Number of heating elements	26
Outside diam. of tubes	0.035 m. *(1 3/8")*
Inside diam. of tubes	0.028 m. *(1 1/8")*
Total heating surface in contact with gases	25.48 m² *(274 sq. ft.)*

Boiler :

Outside length of outside firebox	top	2.543 m. *(8' 4 1/4")*
	bottom	2.309 m. *(7' 6 29/32")*
Outside width of outside firebox	front	2.3415 m. *(7' 8 5/32")*
	rear	2.181 m. *(7' 1 7/8")*
Inside diameter of large barrel ring		1.680 m. *(5' 6 5/32")*
Length of barrel		5.899 m. *(19' 4 1/4")*
Thickness of barrel plates		0.019 m. *(3/4")*
Distance between rail top and bottom of foundation ring		1.202 m. *(3' 11 5/16")*
Inside length of smokebox		2.500 m. *(8' 2 7/16")*
Inside diameter of smokebox		1.718 m. *(5' 7 5/8")*
Total boiler capacity		11.740 m³ *(414.6 cu. ft.)*
Water capacity of boiler		8.360 m³ *(29.5 cu. ft.)*
Normal water level above firebox crown, front		0.114 m. *(4 1/2")*
Boiler pressure		16 kgr./cm² *(228 lb./in²)*
Diameter of safety valves		0.1016 m. *(4 5/32")*
Inside diameter of each chimney	top	0.440 m. *(17 5/16")*
	bottom	0.330 m. *(13")*
Distance between chimney centres		0.460 m. *(18 1/8")*
Distance between feedwater couplings centres		0.840 m. *(2' 9 1/16")*

Frame :

Distance between main frames	1.234 m. *(4' 0 19/32")*
Thickness of main frames	0.028 m. *(1 1/8")*
Distance between handrail posts centres	2.600 m. *(8' 6 23/64")*

Wheels and axles :

Wheel diameter reckoned with 0.070 m. *(2 3/4")* tyres	1st and 2nd pairs	1.000 m. *(3' 3 3/8")*
	3rd, 4th and 5th pairs	2.000 m. *(6' 6 3/4")*
	6th pair	1.360 m. *(4' 5 35/64")*
Distance between tyres (inside)		1.360 m. *(4' 5 35/64")*

		Diam.	Length	From centre to centre
Journals	1st and 2nd axles	0.170 m. *(6 11/16")*	0.270 m. *(10 5/8")*	1.090 m. *(3' 7")*
	3rd axle	0.220 m. *(8 11/16")*	0.230 m. *(9 1/16")*	1.240 m. *(4' 0 53/64")*
	4th and 5th axles	0.220 m. *(8 11/16")*	0.250 m. *(9 7/8")*	1.150 m. *(3' 99/32")*
	6th axle	0.200 m. *(7 7/8")*	0.280 m. *(11 1/32")*	1.120 m. *(3' 8 5/64")*

3rd, 4th and 5th pairs of wheels : 16 plates, 0.110 × 0.012 m. *(4 3/8" × 15/32")*	chord	1.0875 m. *(3' 6 27/32")*
	camber	0.070 m. *(2 3/4")*
6th pair of wheels — Helical, cylindrical, 6 1/4 turns	Aver. diam. of coil	0.155 m. *(6 1/8")*
	Aver. diam. of wire	0.037 m. *(1 29/64")*
	Free height	0.3652 m. *(14 11/32")*

Motion :

	Hp.	Lp.
Cylinder diameter	0.440 m. *(17 5/16")*	0.650 m. *(25 5/8")*
Piston stroke	0.650 m. *(25 5/8")*	0.650 m. *(25 5/8")*
Length of connecting rods	3.000 m. *(9' 10 1/8")*	1.675 m. *(5' 6")*
Distance between centres lines of cylinders	2.230 m. *(7' 3 25/32")*	0.690 m. *(2' 3 1/8")*
Distance between centres lines of valve rods	2.280 m. *(7' 5 3/4")*	0.705 m. *(2' 3 3/4")*
Distance between centre lines of links	2.465 m. *(8' 1")*	—
Inclination of cylinders	0°	4° 0' 9"

The driving cranks for the high-pressure cylinders make an angle of 175°59'51" with the driving cranks of the low-pressure cylinders.

Valve gear :

	Hp.	Lp.
Type of valve gear	Walschaerts	Conjugated
Type of valves	Piston	Piston
Piston valve diameter	0.240 m. *(9 7/16")*	0.360 m. *(14 3/16")*
Radius of eccentricity	0.160 m. *(6 5/16")*	—
Max. stroke of piston valves	0.172 m. *(6 25/32")*	0.2215 m. *(8 23/32")*
Steam lap (inside)	0.034 m. *(1 11/32")*	0.034 m. *(1 11/32")*
Exhaust lap (outside)	—0.004 m. *(—5/32")*	0.008 m. *(5/16")* front 0.006 m. *(15/64")* rear.
Max. cut-off in full gear	79.75 %	87.45 %
Admission ports	0.578 m. × 0.040 m. *(22 3/4" × 1 9/16")*	0.891 m. × 0.050 m. *(35" × 1 31/32")*
Volume of receiver		0.382 m³ *(13.5 cu. ft.)*

On each side of the locomotive a single valve motion operates the high-pressure piston valve directly, and the low-pressure cylinder valve-gear through a countershaft and rocking lever.

Weight :

		Kgr.	Lb.
Empty engine (tyres half-worn)		87 540	*192 990*
Hot water at normal level		7 740	*17 060*
Coal assumed to be in firebox		1 300	*2 870*
Sand (sandbox half full)		150	*330*
Locomotive in average working order	1st pair of wheels	12 120	*26 720*
	2nd pair of wheels	12 120	*26 720*
	3rd pair of wheels	18 500	*40 790*
	4th pair of wheels	18 500	*40 790*
	5th pair of wheels	18 500	*40 790*
	6th pair of wheels	16 990	*37 450*
	Total	96 730	*213 260*

These locomotives are fitted with a double blast pipe with cross-bars, heavy duty brake equipment with bi-compound pumps, electric lighting and equipment for steam heating of trains.

They have a Bourdon mechanical lubricator feeding the four steam chests, the two **Hp.** cylinders and the six oil boxes of the driving axles, as well as slide bars with large-capacity oil wells for long non-stop journeys.

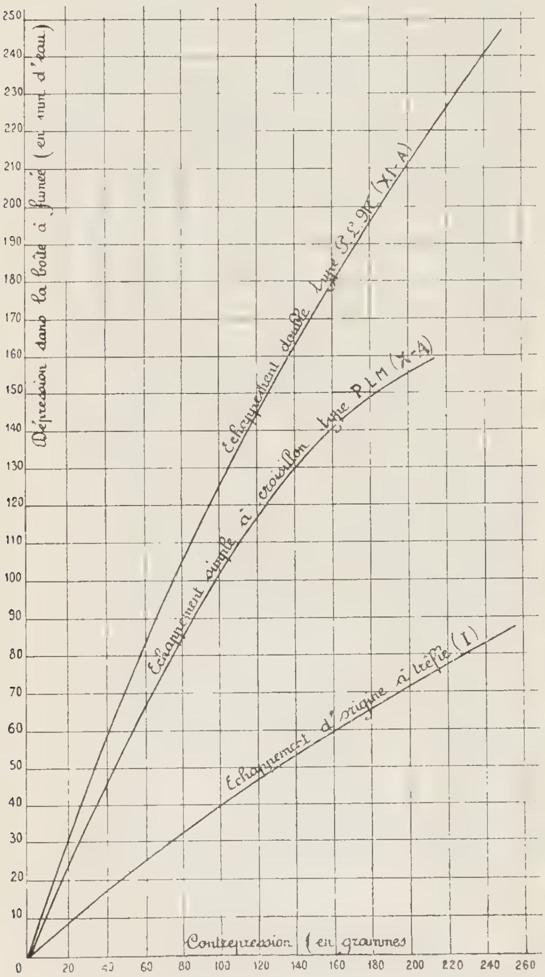


Fig. 10. — Comparative characteristic curves of P. L. M. blast pipes.

Explanation of French terms:

Dépression... = vacuum in smokebox, in millim. of water. — Echappement double... = P.L.M. (XI-A) type double blast pipe. — Echappement simple... = P.L.M. (X-A) cross-bar type single blast pipe. — Echappement d'origine... = original clover-leaf type (I) blast pipe.

ves. — The P. L. M. has found it possible to secure a considerable reduction in the weight of the piston valves on the *Pacific* locomotives by a modification in design, derived from the shape of the piston valves used by the Reichsbahn. Figure 13 shews the form of lightened piston valves adopted, the weight of which gives a reduction of more than 40 % for the high-pressure, and more than 30 % for the low-pressure piston valves.

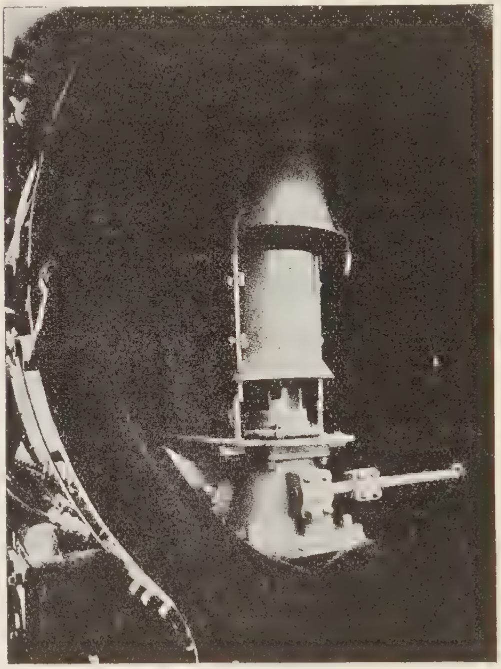


Fig. 11. — P. L. M. double blast pipe with cross-bars and petticoats.

Other « composite » types of piston valve have been tried having a still lower weight. They are composed of two plates welded on a central steel-plate tube, the ends of the plates being provided with a cast-iron head in the form of a sleeve. Grooves are provided in the head to accommodate the rings.

The following table gives the weight

reductions obtained with the different types on a 4-6-2 locomotive :

Weight of piston valves :	HP. Kgr.	HP. *(Lb.)*	LP. Kgr.	LP. *(Lb.)*
Ordinary type . .	68	*(150)*	96	*(212)*
Reichsbahn type .	38	*(83.8)*	60.5	*(133.3)*
Composite type. .	32	*(70.5)*	56	*(123.4)*

6. *Improved starting.* — Up to the present *Pacific* locomotives had been started by introducing into the receiver, at a pressure of 6 kgr./cm² (85 lb./sq. in.), steam taken direct from the boiler.

In order to use this afflux of steam more profitably, the receiver has been connected to the superheater header by a short, large-diameter tube operated by a special heavy-duty Cocard valve, and this has increased the starting pressure in the receiver from 6 to 10 kgr./cm² (85 to 142 lb./sq. in.).

In addition, the compressed air sanding gear has been replaced by steam sanding.

B. — Results obtained in comparative trials of the 231-D and 231-G locomotives.

(a) Power of the locomotives (figs. 4 and 5).

The maximum power, again defined as the sustained effort over 100 km. (62 miles) were as shown in Table 6 hereafter.

Table 6.

Hourly speed.	Cut-off HP, %.	Indicated horse-power.	Effective horse-power.
100 km. *(62 miles).*	55	2 786	2 131
120 km. *(75 miles)*	50	2 750	1 963

On a short run (20 km. = 12.4 miles) the engine developed at 100 km. (62 miles) an hour, an indicated horse-power of 2 963, and an effective horse-power of 2 351 with 65 % cut-off.

Further, an indicated horse-power of 2 385 and an effective horse-power of 1 755 at 100 km. an hour was obtained with 45 % cut-off to the high-pressure cylinders.

Some indicator diagrams are shown in fig. 14.

The application of a P. L. M. double blast pipe and new low-pressure cylinders to the 231-D engines gave the following results;

— for equal characteristics the actual power was increased by 12 % at 100 km. an hour;

— the maximum effective power was increased by 36 % at 100 km. an hour, and 63 % at 120 km. an hour. (In practice the distances covered may have been increased by 10 %).

— the increase in power is much greater at 120 km. (75 miles) than at 100 km. (62 miles). (The improvement in the diagrams is therefore the greater the higher the speed).

(b) Temperature of the steam (high-pressure steam chests).

From 374° to 383° C. according to the running conditions.

The temperature is therefore practically the same as on the original engines.

(c) Combustion and draught.

The combustion reached 513 kgr./m² (105 lb./sq. ft.) per hour on a trial at 100 km., with 55 % cut-off.

(d) Efficiency of the boiler.

The calculated steaming power of the boiler reached 102 kgr./m² (20.9 lb./sq. ft.) per hour, shewing an increase of 45 % over the original 4-6-2 engine.

(e) Consumption and overall efficiency (See Table 7).

Table 7.

Hourly speed.	P_i.	P_e.	$\frac{P_e}{P_i}$.	Consumption per indicated horse-power/hour.		Consumption per effective horse-power/hour.		Overall efficiency.	
				water	coal	water	coal	indicated	effective
				kgr. *(lb.)*	kgr. *(lb.)*	kgr. *(lb.)*	kgr. *(lb.)*		
100 km. *(62 miles)*	2 150	1 600	0.74	5.800 *(12.78)*	0.700 *(1.54)*	7.800 *(17.20)*	0.945 *(2.08)*	0.11	0.08
	2 342	1 724	0.74	5.590 *(13.21)*	0.680 *(1.50)*	7.600 *(16.76)*	0.930 *(2.05)*	0.11	0.08
	2 400	1 800	0.75	5.770 *(12.72)*	0.700 *(1.54)*	7.700 *(16.98)*	0.930 *(2.05)*	0.11	0.08
	2 600	2 000	0.77	6.070 *(13.38)*	0.740 *(1.63)*	7.900 *(17.42)*	0.960 *(2.12)*	0.10	0.08
120 km. *(75 miles)*	2 000	1 300	0.65	6.240 *(13.76)*	0.760 *(1.68)*	9.600 *(21.16)*	1.180 *(2.60)*	0.10	0.07
	2 352	1 639	0.70	6.280 *(13.84)*	0.800 *(1.76)*	9.010 *(19.86)*	1.140 *(2.51)*	0.10	0.07
	2 550	1 800	0.71	6.280 *(13.84)*	0.810 *(1.79)*	8.900 *(19.62)*	1.140 *(2.51)*	0.09	0.07
	2 750	2 000	0.73	6.350 *(14.00)*	0.850 *(1.87)*	8.730 *(19.23)*	1.170 *(2.58)*	0.09	0.07

The altered locomotive varied from the original as shown in Table 8 hereafter.

Table 8.

Hourly speed.	Horse-power		Variation in consumption in relation to the original locomotive			
			per indicated horse-power/hour.		per effective horse-power/hour.	
	indicated.	effective.	water.	coal.	water.	coal.
100 km. *(62 miles)*	2 150	1 600	— 6 %	— 18.6 %	— 6 %	— 17.8 %
120 km. *(75 miles)*	2 000	1 300	— 9.6 %	— 21.6 %	— 9.6 %	— 20.7 %

Thus for equal power developed at equal speed :

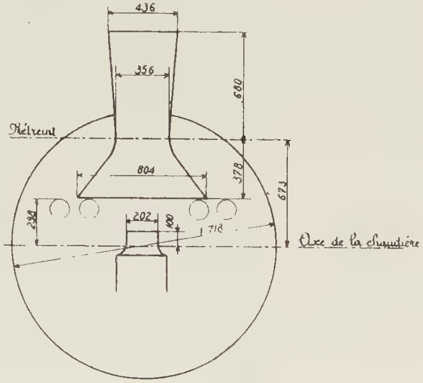
— *the water economy* is 6 % at 100 km. an hour, and 10 % at 120 km.;

— *the fuel economy is very large,* reaching 18 % at 100 km. an hour and 20 % at 120 km.;

— *the economy is greater at 120 km.*

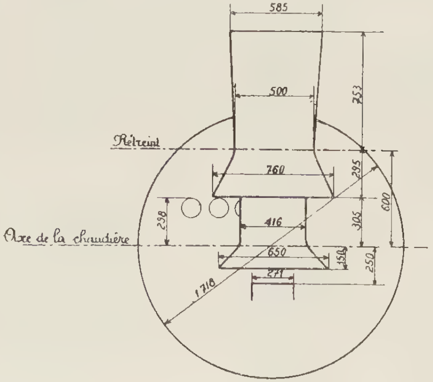
1.

Original clover-leaf (I) type blast pipe
(356-mm. = 14 in. ∅ chimney).



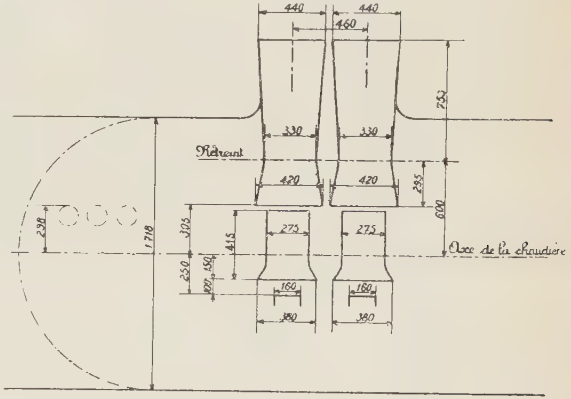
2.

P. L. M. (X-A) type single blast pipe with cross-bars
(500-mm. = 13 in. ∅ chimney).



3.

P. L. M. (XI) type double blast pipe
(330-mm. = 13 in. ∅ chimney).



		1.	2.	3.
Area of exhaust steam passages	Clover leaf, diameter.	125 mm. (4 29/32 in.)	Cross-bars, ∅ 193 mm. (7 19/32 in.)	83 mm. (3 1/4 in.)
	Fully open exhaust: S_1 cm².	181 (28.1 in²)	260 (40.3 in²)	274 (42.5 in²)
	Reduced exhaust	120 (18.6 in²)	172 (26.7 in²)	181 (28.1 in²)
	Characteristic ratios :			
	$\frac{S_1}{n.V.B.P} =$	0.421	0.605	6.294
	$\frac{S_1}{C} =$	0.877	1.261	0.637
	$\frac{S}{C} =$	»	6.590	1.328
	$\frac{\Sigma}{C} =$	4.826	9.520	5.760

Legend:

C = Total heating surface.

n = Number of low-pressure cylinders.

V B P = Volume, in litres, of one low-pressure cylinder.

S_3 = Cross-sectional area at petticoat, in cm².

Σ = Cross-sectional area at chimney choke, in cm².

Fig. 12. — Comparative main dimensions of the P. L. M. blast pipes.

Note : Rétreint = choke. — Axe de la chaudière = boiler centre line.

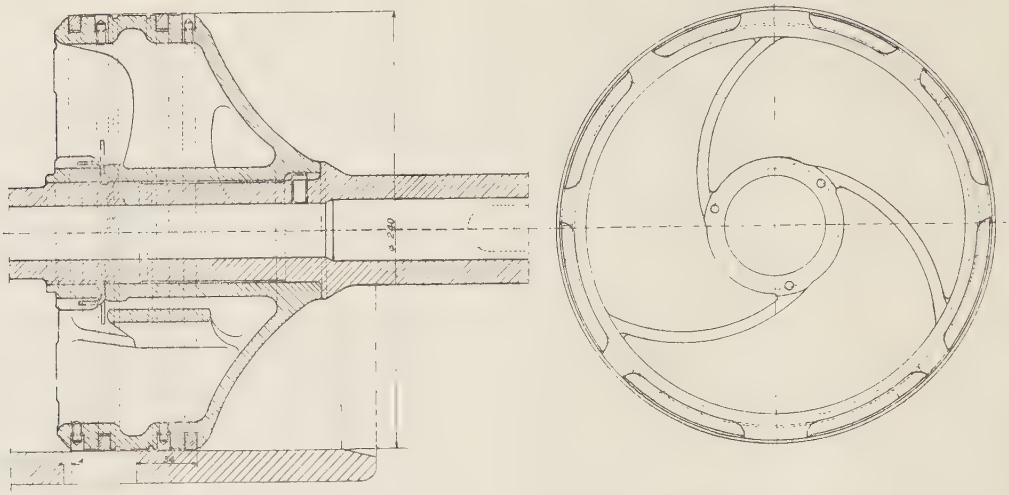


Fig. 13. — Reichsbahn type lightened piston.

than at 100 km. an hour (the improvement in the diagrams is greater at higher speeds);

— *the fuel economy is greater than the water economy* (the fitting of the new exhaust spreads the draught more evenly over the grate area and gives better combustion).

IV. 231-H LOCOMOTIVES.

The 231-H locomotives (figs. 15 and 16) represent a second type of modern P. L. M. *Pacifics*. They differ from the 231-G type by reason of the following modifications :

— boiler pressure increased from 16 to 20 kgr./cm² (228 to 284 lb. per sq. in.);

— high pressure cylinders decreased in diameter, in accordance with the increased pressure;

— use of a Dabeg economiser with mixed elements;

— increased temperature of superheat, consequent upon the increased pressure and the use of a mixed-element economiser;

— increased power of the ACFI, RM type, feed water heater pump.

The 231-H-141 locomotive, which was the prototype of the H class, is a converted D class engine (formerly 231-D-141); however it was decided that the other 231-H locomotives should be obtained by conversion of the oldest Pacifics, that is the E and B classes, with working pressures of 12 and 14 kgr./cm² (171 and 199 lb. per sq. in.) (see I, History), the power of which has up to the present been obviously insufficient for a *Pacific* service.

A. — Special modifications in the 231-H class.

1. *Increased boiler pressure.* — The first trials on the P. L. M. of boilers with pressures of 20 kgr./cm² (284 lb. per sq. in.) date from 1929. At that time the boiler of the 231-D-141 was strengthened to allow the pressure to be increased from 16 to 20 kgr./cm², the steps taken being to increase the diameter of the stays, provide thicker shell rings, and strengthen the tube plate fittings and the dome.

2. *Reduced diameter of the high-pressure cylinders.* — In consequence of the raised boiler pressure, the diameter of the high-pressure cylinders was reduced

from 440 to 400 mm. (17 5/16 to 15 3/4 in.).

Theoretically, a diameter of 406 mm. (16 in.) should have been adopted, in accordance with the following equation:

$$\left(\frac{d_1}{d_2}\right)^2 = \left(\frac{P_2}{P_1}\right)^{\frac{1}{\lambda}}$$

— d_1 and d_2 being the diameters of the high-pressure cylinders,

— P_1 and P_2, the *absolute* steam pressures.

3. *Use of an economiser.* — So as to improve the efficiency of the boiler the 231-D-141 was fitted with a *Dabeg economiser using mixed elements* (fig. 17) fitted in series with the ACFI feed heater.

The temperature of the feed water, which was only 95° C. (203° F.) at the outlet of the ACFI feed heater, was increased to 125° C. (257° F.) at the economiser outlet before entering the boiler, an increase of 30 %.

4. *Improved superheat.* — The increased temperature of the superheat was necessary for two reasons :

(a) Any increase in pressure must be accompanied by an increase in the superheat temperature, as well as a decrease in the size of the high-pressure cylinders. An inspection of the entropy chart shows that when a pressure of 16 kgr./cm^2 (228 lb. per sq. in.) is changed for a pressure of 20 kgr./cm^2 (284 lb. per sq. in.), the increase in temperature must be about 30° C. (54° F.).

(b) the presence of water circulation, even preheated water, within the superheater tubes gives rise to a cooling of the gases and a drop of about 30° C. in the superheat temperature. A further increase of superheat temperature was therefore necessary.

A total increase of 60° C. (108° F.) in superheat temperature is, therefore, necessary.

This result was obtained by the following alterations :

(α) Substitution of a single superheater header by a header with separate chambers.

(β) Replacement of 135 × 143 mm. (5 5/16" × 5 19/32") superheater tubes by 141 × 150 mm. (5 35/64" × 6") tubes;

(γ) Substitution of Schmidt type superheater elements by the Superheater Company's 5 P 4 elements which can be fitted alongside the economiser elements, and are composed of four outward 16 × 24 mm. (5/8" × 15/16") Serve tubes, and one 28 × 35 mm. (1 1/8" × 1 3/8") return tube, joined by a forged spear-head (fig. 18).

(δ) Spear-head of the 5 P 4 elements brought to within 350 mm. (13 3/4 in.) of the firebox tube plate, instead of 450 mm. (17 11/16 in.) as in the case of the Schmidt elements on the 231-D class.

5. *Increased power of the ACFI feed pump.* — Owing to the increased steaming power of the engine and the drop in supplementary load, due to the presence of the economiser, it has been necessary to replace the original type 254/203/203 ACFI feed pump, of 19.5 m^3 (688 cu. ft.) maximum capacity (stroke 260 mm = = 10 1/4 in.), by a new type 325/235/235 ACFI pump, of 37 m^3 (1 306 cu. ft.) capacity (230 mm. = 9 1/16 in. stroke).

B. — Results obtained on trials and comparison of the 231-H and 231-D classes.

1. *Road tests.* — *(a)* Power of the locomotives (fig. 4 and 5).

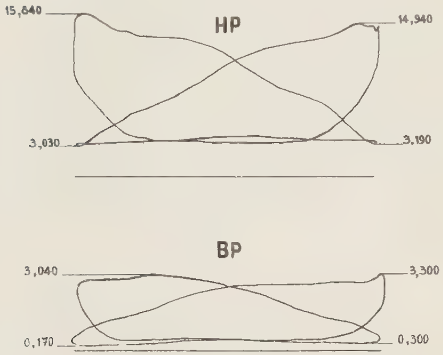
The *maximum sustained power* recorded with the 231-H-141 in the course of trials on the road, on a 100-km. (62 miles) run is given in Table 9 hereafter.

Table 9.

Hourly speed.	Cut-off HP, %.	Indicated H.P.	Drawbar H.P.
100 km. *(62 miles).*	55	3 078	2 482
120 km. *(75 miles)*	50	3 216	2 393

Fig. 14. — Indicato

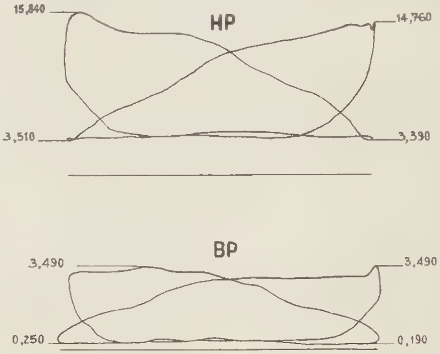
Train A-707 of 12-3-34.
Hp cut-off 45 %, speed 98.8 km./h.



	Front face.	Rear face.	Total.
Horse-power, hp cyls. .	708	757	1 465
Horse-power, lp cyls. .	478	442	920
Total horse-power. . .			2 385

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.598$$

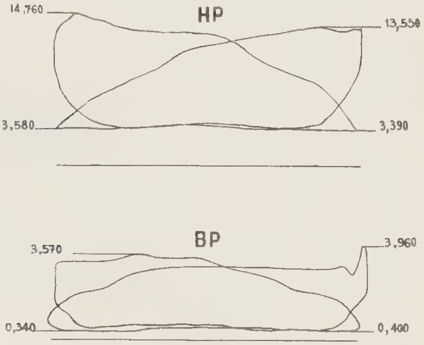
Train A-707 of 15-3-34.
Hp cut-off 50 %, speed 98 km./h.



	Front face.	Rear face.	Total.
Horse-power, hp cyls. .	708	774	1 482
Horse-power, lp cyls. .	515	537	1 052
Total horse-power. . .			2 534

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.585$$

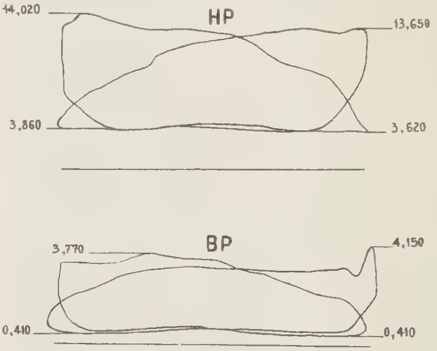
Train A-707 of 16-3-34.
Hp cut-off 55 %, speed 98.9 km./h.



	Front face.	Rear face.	Total.
Horse-power, hp cyls. .	785	856	1 641
Horse-power, lp cyls. .	570	575	1 145
Total horse-power. . .			2 786

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.589$$

Train A-710 of 16-3-34.
Hp cut-off 60 %, speed 99 km./h.

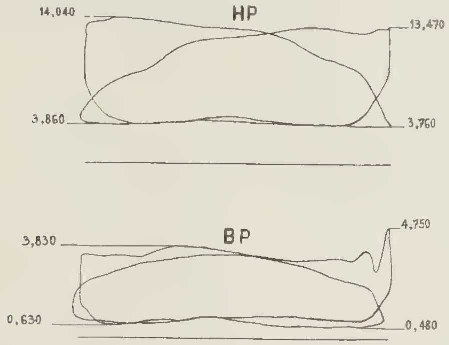


	Front face	Rear face.	Total.
Horse-power, hp cyls. .	846	900	1 746
Horse-power, lp cyls. .	577	563	1 140
Total horse-power. . .			2 886

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.605$$

ns, 231-G locomotives.

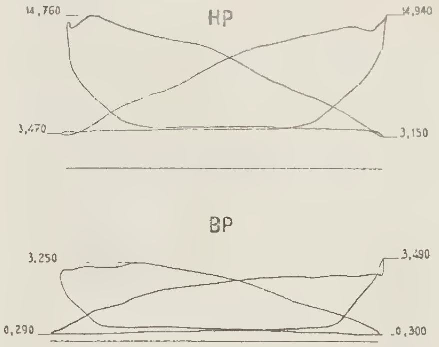
Train A-710 of 16-3-34.
Hp cut-off 65 %, speed 99.4 km./h.



	Front face.	Rear face.	Total.
Horse-power, hp cyls. .	859	908	1 767
Horse-power, lp cyls. .	592	604	1 196
Total horse-power. . .			2 963

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.596$$

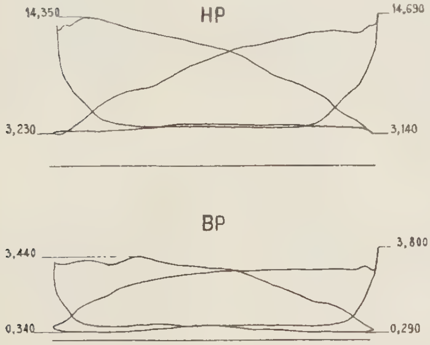
Train A-709 of 20-3-34.
Hp cut-off 45 %, speed 117.8 km./h.



	Front face.	Front face.	Total.
Horse-power, hp cyls. .	691	774	1 465
Horse-power, lp cyls. .	467	529	996
Total horse-power. . .			2 461

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.595$$

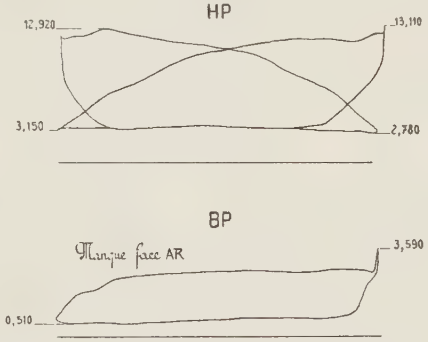
Train A-709 of 21-3-34.
Hp cut-off 50 %, speed 118.5 km./h.



	Front face.	Rear face.	Total.
Horse-power, hp cyls. .	769	844	1 613
Horse-power, lp cyls. .	543	594	1 137
Total horse-power. . .			2 750

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.587$$

Train A-710 of 20-3-34.
Hp cut-off 55 %, speed 119 km./h.



(Rear face missing.)

Note : HP = high pressure.
BP = low pressure.

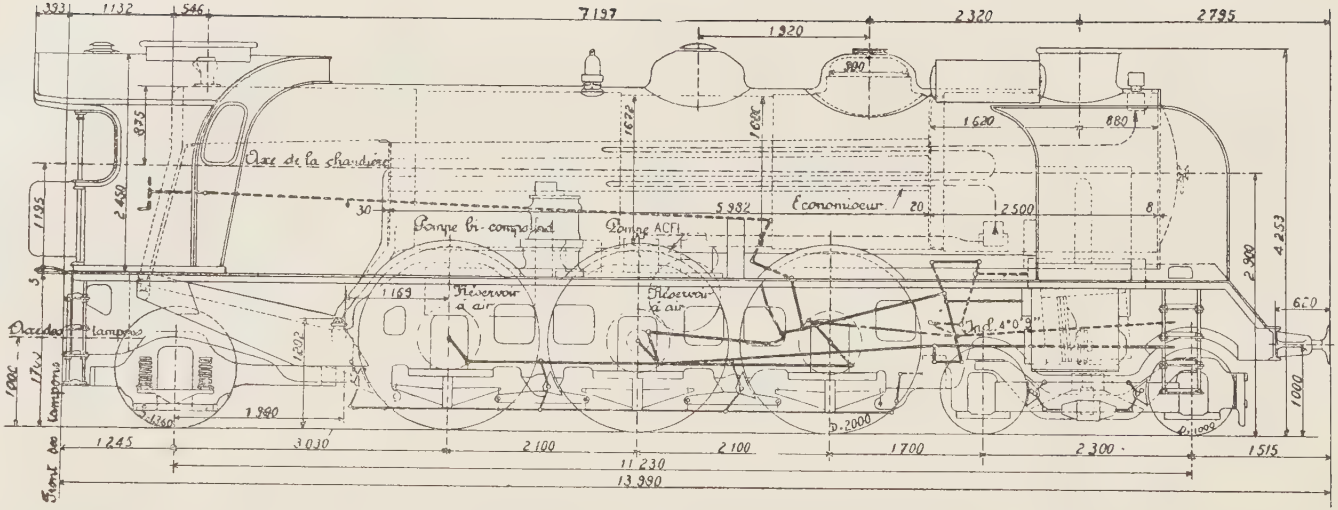


Fig. 16. — Diagram of 231-H locomotives.

Grate :

Full length	2.125 m. (*6' 11 43/64''*)
Width, front	2.086 m. (*6' 10 1/8''*)
Width, rear	1.922 m. (*6' 3 43/64''*)
Area	4.25 m² (*45.2 sq. ft.*)

Outside firebox :

Height of crown sheet above foundation ring, front	1.9952 m. (*6' 6 9/16''*)
Height of crown sheet above foundation ring, rear	1.4807 m. (*4' 10 5/16''*)
Inside length, top	2.280 m. (*7' 5 3/4''*)
Inside length, bottom	2.078 m. (*6' 9 13/16''*)
Inside width, along boiler centre line	1.418 m. (*4' 7 53/64''*)
Inside width, bottom, front	2.086 m. (*6' 9 13/16''*)
Inside width, bottom, rear	1.922 m. (*6' 3 5/16''*)
Thickness of copper, side walls	0.014 m. (*9/16''*)
Thickness of copper, at the bottom	0.014 m. (*9/16''*)
Thickness of copper tube plate	0.030 m. (*1 3/16''*)

Tubes :

Number (smooth steel tubes), Tubes of 0.055 m. (*2 3/16''*) inside diam.	122
Number (smooth steel tubes), Tubes of 0.150 m. (*5 19/32''*) outside diam.	26

Crank pins :

		Diam.	Length.	Centre to centre.
Connecting rod big ends	Hp.	0.130 m. (*5 1/8''*)	0.172 m. (*6 25/32''*)	2.230 m. (*7' 5 51/64''*)
	Lp.	0.220 m. (*8 11/16''*)	0.115 m. (*4 1/2''*)	0.690 m. (*2' 3 1/8''*)
Coupling rods	3rd pair of wheels	0.105 m. (*4 1/8''*)	0.090 m. (*3 35/64''*)	1.910 m. (*6' 3 14/64''*)
	4th pair of wheels	0.180 m. (*7 3/32''*)	0.095 m. (*3 47/64''*)	1.885 m. (*6' 2 13/64''*)
	5th pair of wheels	0.105 m. (*4 1/8''*)	0.090 m. (*3 35/64''*)	1.885 m. (*6' 2 13/64''*)

Lateral play on each side of engine :

Bogie, Pivot	0.060 m. (*2 3/8''*)
Bogie, Axles	0.001 m. (*0.039''*)
3rd and 5th axles	0.001 m. (*0.039''*)
4th axle, Tyres thinned down	0.010 m. (*3 15/16''*)
4th axle, Axles	0.001 m. (*0.039''*)
Bissel truck, Pivot	0.066 m. (*2 5/8''*)
Bissel truck, Axle	0.001 m. (*0.039''*)

Springs :

1st and second pairs of wheels : 15 plates, 0.120 × 0.015 mm. (*4 3/4'' × 19/32''*)	chord	1.245 m. (*4' 1''*)
	camber	0.045 m. (*1 49/64''*)

Thickness	0.055-m. tubes	0.002 m. (*5/64"*)
	0.150-m. tubes	0.0045 m. (*11/64"*)
Distance between tube plates		5.982 m. (*19' 7 1/2"*)

Heating surface :

Firebox	15.43 m² (*166 sq. ft.*)
Tubes (inside area)	187.10 m² (*2 014 sq. ft.*)
Total	202.53 m² (*2 180 sq. ft.*)

Superheater :

Number of 5 P. 4 elements	26
Outside diam. of tubes	0.035 m. and 0.024 m. (*1 3/8" and 15/16"*)
Superheating surface	49.50 m² (*533 sq. ft.*)

Economiser (mixed type) with 6 take-offs :

Number : of preheating elements	22
Outside diam. of tubes	0.035 m. (*1 3/8"*)
Inside diam. of tubes	0.028 m. (*1 1/8"*)
Total heating surface in contact with gases	25.50 m² (*274.4 sq. ft.*)

Boiler :

Outside length of outside firebox	top	2.51 m. (*8' 2 53/64"*)
	bottom	2.282 m. (*7' 5 53/64"*)
Outside width of outside firebox	front	2.313 m. (*7' 7 5/64"*)
	rear	2.153 m. (*7' 0 3/4"*)
Inside diameter of large barrel ring		1.680 m. (*5' 6 5/32"*)
Length of barrel		5.899 m. (*19' 4 1/4"*)
Thickness of barrel plates		0.023 m. (*15/16"*)
Distance between rail top and bottom of foundation ring (front)		1.202 m. (*3' 11 5/16"*)
Inside length of smokebox		2.500 m. (*8' 2 7/16"*)
Inside diameter of smokebox		1.726 m. (*5' 8"*)
Total boiler capacity		11.320 m³ (*400 cu. ft.*)
Water capacity of boiler		7.320 m³ (*258.5 cu. ft.*)
Normal water level above firebox crown, front		0.114 m. (*4 1/2"*)
Boiler pressure		20 kgr./cm² (*284 lb./in²*)
Diameter of safety valves		0.1016 m. (*4"*)
Indide diameter of each unit of double chimney	top	0.440 m. (*17 5/16"*)
	bottom	0.330 m. (*13"*)
Distance between chimney centres		0.460 m. (*16 1/8"*)
Distance between feedwater couplings centres		0.840 m. (*2' 9 1/16"*)

Frame :

Distance between main frames	1.234 m. (*4' 0 19/32"*)
Thickness of main frames	0.028 m. (*1 1/8"*)
Distance between handrail posts centres	2.600 m. (*8' 6 23/64"*)

Wheels and axles :

Wheel diameter reckoned with 0.070 m. (*2 3/4"*) tyres	1st and 2nd pairs	1.000 m. (*3' 3 3/8"*)
	3rd, 4th and 5th pairs	2.000 m. (*6' 6 3/4"*)
	6th pair	1.360 m. (*4' 5 35/64"*)
Distance between tyres (inside)		1.360 m. (*4' 5 35/64"*)

		Diam.	Length	From centre to centre
Journals	1st and 2nd axles	0.170 m. (*6 11/16"*)	0.270 m. (*10 5/8"*)	1.090 m. (*3' 7"*)
	3rd axle	0.220 m. (*8 11/16"*)	0.230 m. (*9 1/16"*)	1.240 m. (*4' 0 5/64"*)
	4th and 5th axles	0.220 m. (*8 11/16"*)	0.250 m. (*9 7/8"*)	1.120 m. (*3' 8 5/64"*)
	6th axle	0.200 m. (*7 7/8"*)	0.280 m. (*11 1/32"*)	1.120 m. (*3' 8 5/64"*)

3rd, 4th and 5th pairs of wheels : 16 plates, 0.110 × 0.012 m. (*4 3/8" × 15/32"*)	chord	1.0875 m. (*3' 6 13/16"*)
	camber	0.070 m. (*2 3/4"*)
6th pair of wheels — Helical, cylindrical, 6 1/4 turns	Aver. diam. of coil	0.155 m. (*6 1/8"*)
	Aver. diam. of wire	0.037 m. (*1 29/64"*)
	Free height	0.3652 m. (*14 11/32"*)

Motion :

	Hp.	Lp.
Cylinder diameter	0.400 m. (*15 3/4"*)	0.650 m. (*25 5/8"*)
Piston stroke	0.650 m. (*25 5/8"*)	0.650 m. (*25 5/8"*)
Length of connecting rods	3.000 m. (*9' 10 1/8"*)	1.675 m. (*5' 6"*)
Distance between centres lines of cylinders	2.230 m. (*7' 3 25/32"*)	0.690 m. (*2' 3 1/8"*)
Distance between centres lines of valve rods	2.280 m. (*7' 5 3/4"*)	0.705 m. (*2' 3 3/4"*)
Distance between centre lines of links	2.465 m. (*8' 1"*)	—
Inclination of cylinders	0°	4° 0' 9"

The driving cranks for the high-pressure cylinders make an angle of 175°59'51" with the driving cranks of the low-pressure cylinders.

Valve gear :

	Hp.	Lp.
Type of valve gear	Walschaerts	Conjugated
Type of valves	Piston	Piston
Piston valve diameter	0.240 m. (*9 7/16"*)	0.360 m. (*14 3/16"*)
Radius of eccentricity	0.160 m. (*6 5/16"*)	—
Max. stroke of piston valves	0.172 m. (*6 25/32"*)	0.2215 m. (*8 23/32"*)
Steam lap (inside)	0.034 m. (*1 11/32"*)	0.034 m. (*1 11/32"*)
Exhaust lap (outside)	—0.004 m. (*—5/32"*)	0.008 m. (*5/16"*) front 0.006 m. (*15/64"*) rear
Max. cut-off in full gear	79.75 %	87.45 %
Admission ports	0.580 m. × 0.040 m. (*22 13/16" × 1 9/16"*)	0.891 m. (*35"*) × 0.054 m. (*2 1/8"*) front 0.052 m. (*2 1/16"*) rear

On each side of the locomotive a single valve motion operates the high-pressure piston valve directly, and the low-pressure cylinder valve-gear through a countershaft and rocking lever.

Weight :

		Kgr.	*Lb.*
Empty engine (tyres half-worn)		96 030	*21 170*
Hot water at normal level		7 320	*16 140*
Coal assumed to be in firebox		1 300	*2 870*
Sand (sandbox half full)		150	*330*
Locomotive in average working order	1st pair of wheels	14 600	*32 190*
	2nd pair of wheels	14 600	*32 190*
	3rd pair of wheels	19 000	*41 890*
	4th pair of wheels	19 000	*41 890*
	5th pair of wheels	19 000	*41 890*
	6th pair of wheels	18 600	*41 000*
	Total	104 800	*231 050*

These locomotives are provided with a P. L. M. double blast pipe, cylinders with enlarged section steam passages, and an A. C. F. I. « Integral » type feed heater, with a No. 325 pump. They are equipped for hauling steam-heated trains.

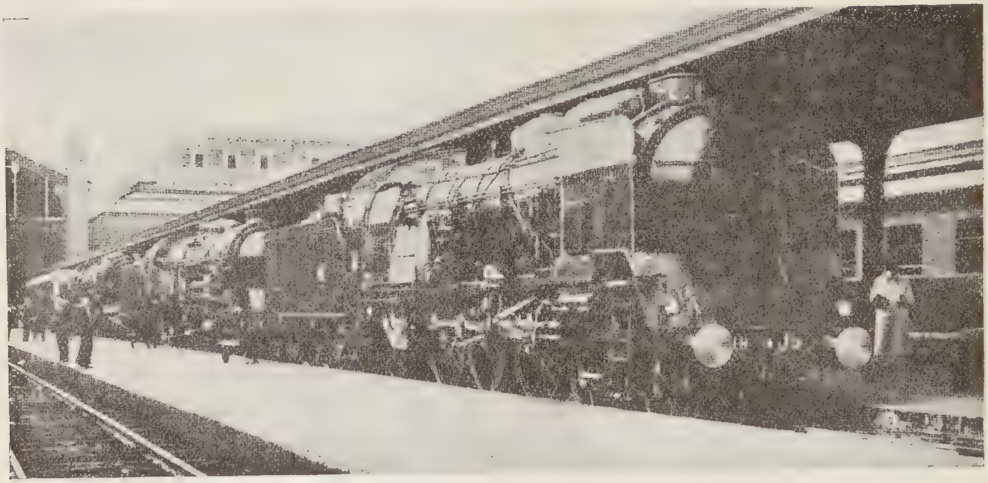


Fig. 15. — Engine 231-H-141 at the exhibition held in June, 1937, in Paris, on the occasion of the International Railway Congress.

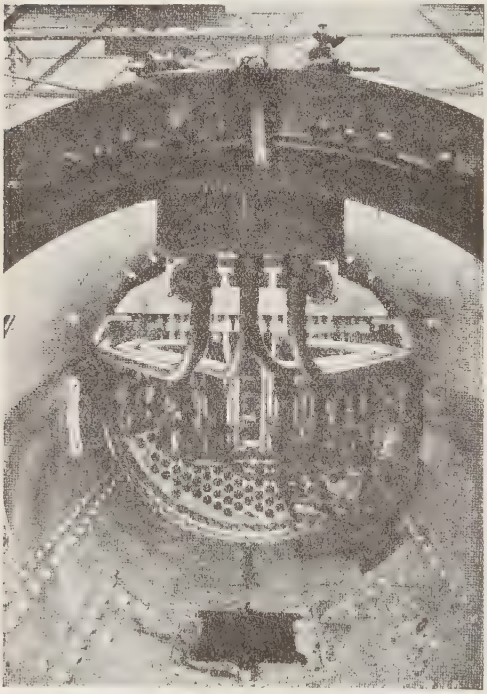


Fig. 17. — Dabeg economiser with mixed elements.

Compared with the 231-G, the increase in power, with equal cut-offs, is 16 % at 100 km. per hour, and 21 % at 120 km.

Compared with the original 231-D engine, the *maximum sustained power* is increased by 58 % at 100 km. an hour, and 87 % at 120 km.

Moreover, the 231-H has developed at 100 km. over a distance of 20 km. (12.4 miles) an I.H.P. of 3 321 and a D.B.H.P. of 2 700 at 60 % cut-off.

Some indicator diagrams are reproduced in fig. 19.

(b) Temperature of the feed water.

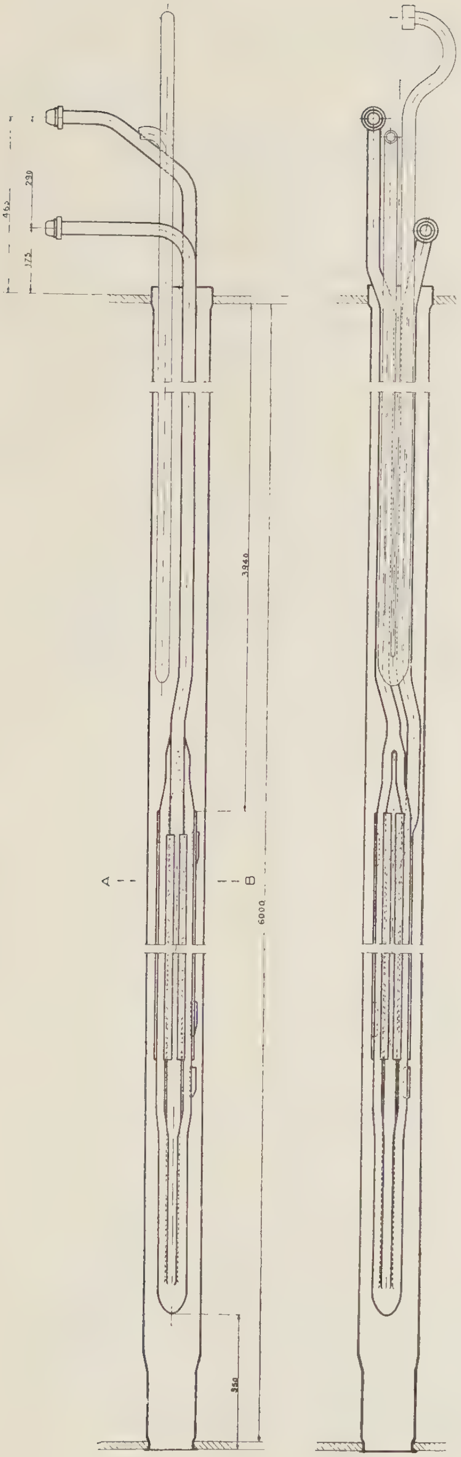
The temperature of the water at the economiser outlet reached 125° C. (257° F.), whilst the temperature of the water at the ACFI feed heater outlet was 95° C. (203° F.).

(c) Temperature of the superheated steam.

The temperature of the superheated steam in the steam chests was 400°.

(d) Consumption and efficiency.

With a D.B.H.P. of 2 200 at 100 km.



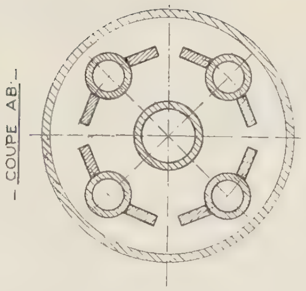


Fig. 18. — 5 P 4 superheater element (mounted with an economiser element).

(62 miles) an hour, the consumption per horse-power/hour was 0.970 kgr. (2.13 lb.) of coal, and 7.2 kgr. (15.9 lb.) of water.

With a D.B.H.P. of 2 000 at 120 km. (75 miles) an hour, the consumption per horse-power/hour was 1.1 kgr. (2.42 lb.) of coal and 7.8 kgr. (17.2 lb.) of water.

Figure 20 shows the total indicated and effective horse-powers of the 231-H-141 locomotive.

2. *Trials on the Vitry test plant.* — The 231-H-141 engine was, in Juli 1936, subjected to power and consumption tests on the Vitry plant.

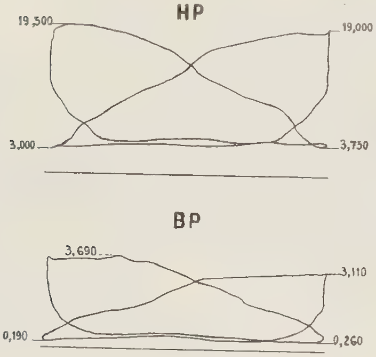
It was found possible, during a *long duration test,* to *sustain 3 000* H.P. *at the wheel tread* at speeds of 100 and 120 km per hour. Table 10 below sums up the results obtained.

On the other hand, during a power test, the locomotive 231-H-141, at a speed of 117 km. (72.7 miles) an hour and 50 % cut-off to the high-pressure cylinders, developed 3 120 H.P. at the wheel tread.

That this figure is slightly higher than the one obtained during the long-duration trial is due to the fact that during the power trial, which was very short, the exhaust remained in notch 3, whilst in the consumption trial the exhaust had to be closed to notch 8.

Fig. 19. — **Indicator d**

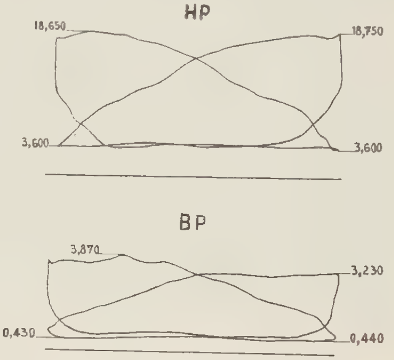
Train 145-D of 11-10-34.
Hp cut-off 50 %, speed 99.6 km./h.



	Front face.	Rear face.	Total.
Horse-power, hp cyls. .	818	819	1 637
Horse-power, lp cyls. .	450	545	995
Total horse-power. . .			2 632

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.622.$$

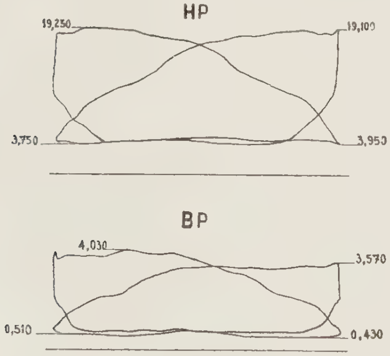
Train 145-D of 13-10-34.
Hp cut-off 45 %, speed 99.2 km./h.



	Front face.	Rear face.	Total.
Horse-power, hp cyls. .	898	884	1 782
Horse-power, lp cyls. .	512	587	1 099
Total horse-power. . .			2 881

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.619$$

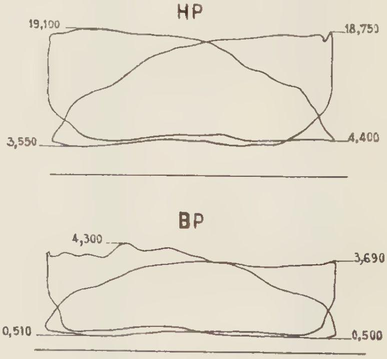
Train 145-D of 16-10-34.
Hp cut-off 50 %, speed 98.9 km./h.



	Front face.	Rear face.	Total.
Horse-power, hp cyls. .	955	944	1 899
Horse-power, lp cyls. .	557	622	1 179
Total horse-power. . .			3 078

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.617$$

Train 144-D of 13-10-34.
Hp cut-off 60 %, speed 99.3 km./h.

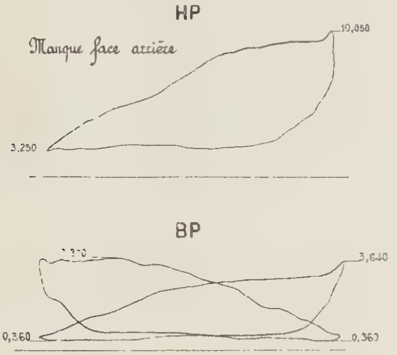


	Front face.	Rear face.	Total.
Horse-power, hp cyls. .	1 009	1 009	2 018
Horse-power, lp cyls. .	632	671	1 303
Total horse-power. . .			3 321

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.608$$

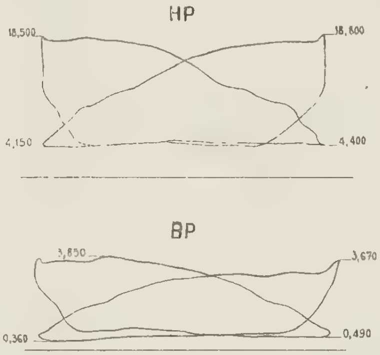
, 231-H locomotives.

Train 147-D of 19-10-34.
Hp cut-off 45 %, speed 118.6 km./h.



	Front face.	Rear face.	Total.
Horse-power, hp cyls. .	922		
Horse-power, lp cyls. .	487	579	1 066

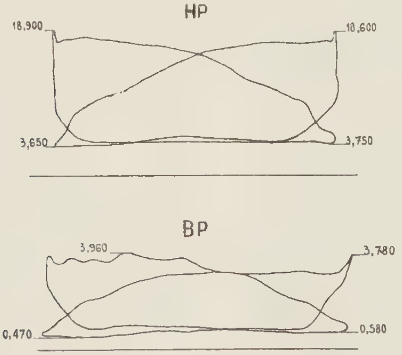
Train 147-D of 20-10-34.
Hp cut-off 50 %, speed 117.8 km./h.



	Front face.	Rear face.	Total.
Horse-power, hp cyls. .	1 000	1 027	2 027
Horse-power, lp cyls. .	536	653	1 189
Total horse-power. . .			3 216

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.630$$

Train 144-D of 19-10-34.
Hp cut-off 55 %, speed 117.1 km./h.



	Front face.	Rear face.	Total.
Horse-power, lp cyls. .	1 060	1 064	2 124
Horse-power, hp cyls. .	539	636	1 175
Total horse-power. . .			3 299

$$\frac{\text{Horse-power hp cyls.}}{\text{Horse-power hp + lp cyls.}} = 0.643$$

Table 10.

Hourly speed.	Cut-off, HP cyl., %	Exhaust closed to notch :	Time test lasted.	Horse-power at wheel tread.	Consumption per H.P./hour at the wheel tread	
					coal.	water.
100 km. *(62 miles).*	50	7	1 h. 30 m.	3 032	0.881 kgr. *(1.940 lb.)*	5.78 kgr. *(12.74 lb.)*
120 km. *(75 miles).*	58	3 and 8	1 h. 41 m.	2 924	0.898 kgr. *(1.960 lb.)*	5.94 kgr. *(13.18 lb.)*

V. 231-K LOCOMOTIVES.

The K class engines are a third type of modern *Pacific* locomotive operated by the P. L. M. They are the former 231-C class which were converted to 231-G; the original release type reversing gear has, however, been retained (see I, History), partly in order to keep the conversion cost down to a minimum, but principally to allow complete independence of the HP and LP valve gears, if necessary.

A trial of the latter arrangement is at present being carried out on a 231-K locomotive.

The advantage of independent valve gear is the more marked the less the locomotives are developing their full power. When an engine with conjugated valve gear, such as the 231-G or 231-H, has to haul a light train at high speed on an easy gradient, it is not possible to raise the running speed as much as would be desirable, since the high-pressure steam admission would be excessively reduced (1); in catering for the low power required, therefore, it is necessary partially to throttle at the regulator, which lowers the efficiency of the engine.

Whilst conjugated valve gear is therefore subject to this drawback, it does, on the other hand, offer the advantage of simplicity.

Trials being carried out with the 231-G and 231-K class engines, which differ only in the control of the steam distribution, should permit of a definite

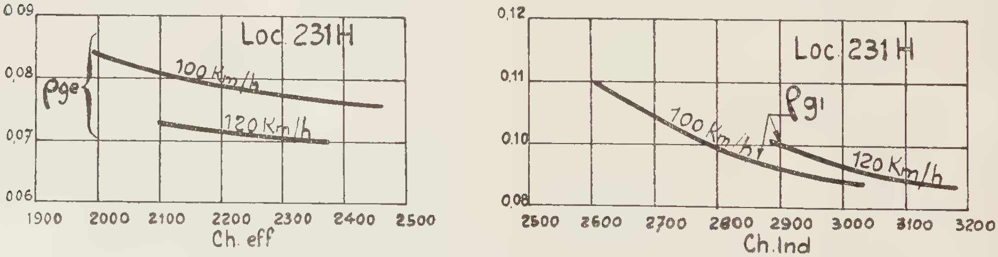


Fig. 20. — Total efficiency (actual and indicated) of 231-H locomotives

opinion being formed on this very controversial question.

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(1) On the P. L. M. *Pacifics* with conjugated valve gear it is not practically possible to sustain a speed of 120 km. per hour with a high-pressure cut-off of less than 40 % (equivalent to a low pressure cut-off of 52 %). On the other hand, with the 231-K having completely independent valve gear, a speed of 120 km. per hour can be maintained with 20 % high-pressure cut-off and 50 % low-pressure cut-off.

Another thing, the P. L. M. have been questioning whether it would not be possible to improve starting to a greater extent (see III. A. 6) by adopting, in spite of the resultant complication, an arrangement for separating the high and low-pressure groups at the steam take-offs. Trials are being envisaged which should show if it is necessary again to sacrifice efficiency in order to maintain simplicity.

VI. TRIAL OF POPPET VALVES.

In conclusion, mention must also be made of a trial being undertaken on the 231-K class of Dabeg poppet valves, with oscillating cams.

VII. SUMMARY.

The foregoing notes show that the P. L. M. *Pacific* locomotives are being progressively modernised, with the idea of obtaining *at a minimum of expense,* and therefore with a minimum of alteration, *as great an increase in efficiency as possible.*

Three series of locomotives, the 231-G, 231-H and 231-K, are called upon to replace the four existing classes, 231-B, 231-C, 231-D and 231-E.

The new locomotives, which are four-cylinder compounds with piston valves and P. L. M. variable type double blast pipe, differ only on the points shown in table 11.

Table 11.

—	231-G.	231-H.	231-K.
Boiler pressure	16 kgr./cm^2. *(228 lb./sq. in.).*	20 kgr./cm^2. *(284 lb./sq. in.)*	16 kgr./cm^2. *(228 lb./sq. in.).*
Diameter of high-pressure cylinders	440 mm. *(17 5/16")*	400 mm. *(15 3/4")*	440 mm. *(17 5/16")*
Tube arrangement	128 tubes, 51 × 55 mm. *(2 1/64" × 2 11/64")* 26 tubes, 135 × 143 mm. *(5 5/16" × 5 9/32")*	122 tubes, 51 × 55 mm. *(2 1/64" × 2 11/64")* 26 tubes, 141 × 150 mm. *(5 35/64" × 6")*	128 tubes, 51 × 55 mm. *(2 1/64" × 2 11/64")* 26 tubes, 135 × 143 mm. *(5 5/16" × 5 9/32")*
Type of superheater elements	Ordinary Schmidt.	5 P 4	Ordinary Schmidt.
Type of valve gear. . . .	Conjugated.	Conjugated.	Independent high- and low-pressure with low pressure set at 63 %.
Type of feed water heater.	Exhaust steam (ACFI).	Exhaust steam (ACFI), and combustion gases (DABEG).	Exhaust steam (ACFI).

The 231-H and 231-K can *sustain :*

— at 100 km. (62 miles) p. h., 2 800 I.H.P., and 2 150 D.B.H.P.;

— at 120 km. (75 miles) p. h., 2 750 I.H.P., and 2 000 D.B.H.P.

The 231-H can *sustain :*

— at 100 km. p. h., 3 100 I.H.P., and 2 500 D.B.H.P.

— at 120 km. p. h., 3 200 I.H.P., and 2 400 D.B.H.P.

Owing to these modifications, therefore, it may be said that it has been found possible greatly to increase the tractive capabilities of the P. L. M. Pacific locomotives.

[621.43]

Increasing the adhesive weight of railcars,

by Dipl.-Ing. J. L. KOFFMANN, Ware, Herts (England).

Owing to the rapid development of diesel railcars, both designers and operators have been faced with several new problems, particular to this type of vehicle. The ultimate goal of railcar adoption being low first cost and maintenance expenses, coupled with utmost simplicity and dependability in service, it was only natural that mechanical transmission made considerable headway during recent years, and is now widely used with engines up to 500 H.P. While as high a rate of acceleration as possible must be achieved to gain the advantages offered by railcar operation, and while furthermore the power/weight ratio has been steadily increased up to the present 10 to 12 B.H.P. per ton of tare weight, the problem of available adhesive weight is of utmost importance.

In accordance with modern investigations (1), the coefficient of friction between dry rail and wheel at starting is

$$f = \frac{900}{42 + V} + 11.6$$

wherein f is in per cent of the adhesive weight, and V the car speed in km. per hour, the same formula being

$$f = \frac{565}{26 + V} + 11.6$$

for V in m.p.h., these values being reduced to 0.7 with wet rails.

The problem dealt with is best examplified by the following typical example. A railcar with a tare weight of 25 tons is to be powered by a type ADV. 120 four-cylinder two-stroke opposed-piston engine, manufactured by the *Compagnie Lilloise de Moteurs,* and developing 250 B.H.P. at 1 500 r.p.m., while the transmission is of the Mylius air-operated preselective five-speed type, the gear ratios being 3.68, 2.15, 1.42, 1 and 0.738 to 1. The wheel diameter is 2' 9 1/2", and as a maximum speed of 77 m.p.h. is required, the gear ratio of the axle drive is 2.47 to 1. Due to losses in the transmission as well as due to power required for the auxiliary drives, it is assumed that 85 % of the engine output is available for tractive purposes at the wheel rim. The engine is mounted in the driving bogie, the rear axle of which is driven, the axle load being 8 tons.

As shown by Fig. 1, the tractive effort available at the first and second gears is in excess of the limits imposed by adhesion, whilst with wet rails, the wheels would slip on the first, second and third gears as well. In plotting the adhesion limit curves, neither the additional loading or unloading of the driving wheels due to the torque arm reaction, nor the vertical component of the drawbar pull when hauling trailers, or pushing them, respectively, have been taken into account. The possible skidding of the driving wheels when starting, however, limits the rate of acceleration, and consequently to some extent the value of the power output available. A solution can be found in employing a double-end transmission, driving both axles through bevel gears, but this solution, besides being expensive in first cost and maintenance, sometimes cannot be adopted

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(1) Dr. H. KOTHER : « Fahrzeitermittlung und Bestimmung der Beanspruchung der Fahrmotoren und des Transformators elektrischer Triebfahrzeuge », *Elektrische Bahnen,* December 1938, page 305.

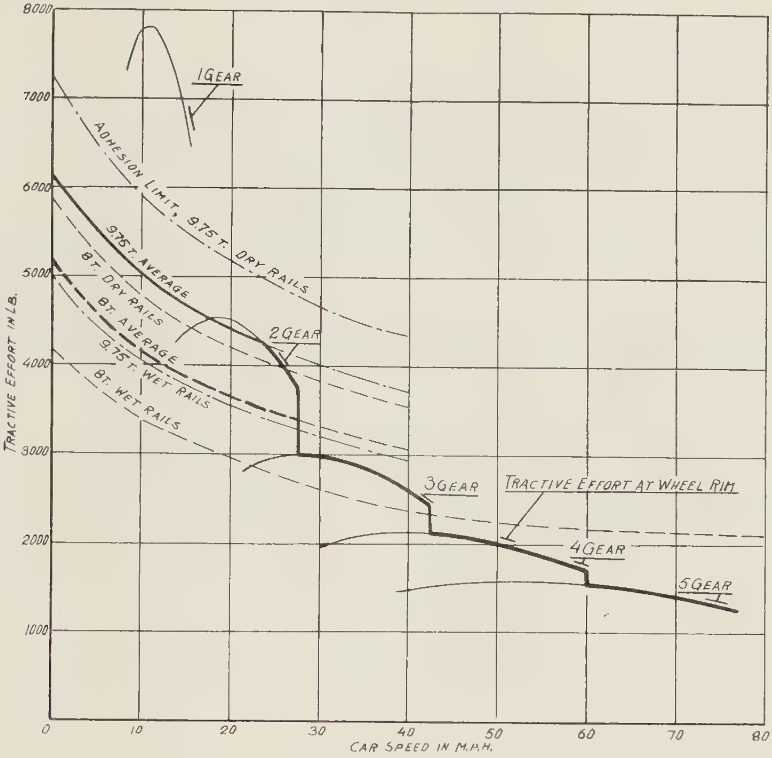


Fig. 1.

due to limitations of the bogie wheelbase.

An improvement at negligible costs can be achieved by employing a vertical air cylinder placed in the car body, above the driving axle. When admitting air into this cylinder an additional portion of the car weight will be transferred to the driving axle, thus raising the adhesion limit, and consequently the available tractive effort. In accordance with Fig. 2, the pressure P in the air cylinder would unload the bolsters of the driving and trailing bogies by the amount

$$L_D = P \frac{l - a}{l}$$

$$L_T = P \frac{a}{l}$$

respectively, while the four car axles will be loaded or unloaded by the amount :

$$L_1 = - P \frac{a - 0\,5\,b}{b} - 0.5\,L_D$$

$$L_2 = P \frac{a + 0.5\,b}{b} - 0.5\,L_D$$

$$L_3 = 0.5\,L_T$$

$$L_4 = 0.5\,L_T$$

respectively.

Coming back to our example, the 250-B.H.P. car with single axle drive, a driving bogie wheelbase of 10.5 feet, bolster centres at 36.75 feet, employing a standard 12" brake cylinder placed at a distance of 6.56 feet from the bogie centre, which, with an air pressure of

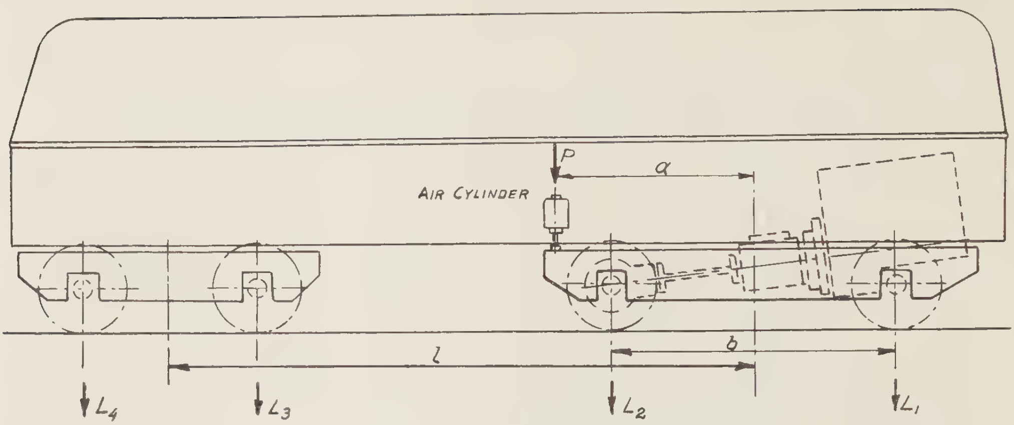


Fig. 2.

70 lb. per square inch, develops a vertical push of 2.4 tons, we obtain :

$$L_D = 2.4 \frac{36.75 - 6.56}{36.75} = 1.97 \text{ T}$$

$$L_T = 2.4 \frac{6.56}{36.75} = 0.43 \text{ T}$$

$$L_1 = -2.4 \frac{6.56 - 0.5 \times 10.5}{10.5} - 0.5 \times 1.97 = -1.32 \text{ T}$$

$$L_2 = 2.4 \frac{6.56 + 0.5 \times 10.5}{10.5} - 0.5 \times 1.97 = 1.75 \text{ T}$$

$$L_3 = 0.5 \times -0.43 = -0.215 \text{ T}$$

$$L_4 = 0.5 \times -0.43 = -0.215 \text{ T.}$$

The increase in adhesive weight in this particular instance, therefore; amounts to more than 20 %, the results thus achieved being shown in Fig. 1. As an increased adhesive weight is of importance on the first three gears, the application of the air cylinder can be left to the discretion of the driver by providing an operating push-button at the driver's stand, or can be applied automatically by admitting air via an electromagnetic valve energised when applying the gears concerned. Thus, the arrangement described offers a simple and inexpensive solution of raising the limits of adhesion with railcars when multi-axle drive is not desired, owing to financial or constructional restrictions.

[621. 4 (.44)]

The new producer-gas railcars of the French National Railways Company,

by Mr. HENRY MARTIN,

Ingénieur des Arts et Manufactures.

(*Le Génie Civil.*)

The use of producer gas for feeding the internal combustion engines of motor vehicles has increased greatly during recent years because of the large economy in working resulting from the employment of a gas-producer for wood or charcoal. In practice, a consumption of 100 lb. of charcoal corresponds to a consumption of 8 Br. gallons of petrol; the relative costs are 35 fr. and 116 fr., respectively, showing a saving of 70 % in favour of charcoal.

The French Railways have, therefore, been induced to consider fuelling railcars with producer gas. Problems of weight have made the use of charcoal preferable to that of wood in the gas-producers.

The best charcoals come from selected woods such as oak, hornbeam, beech or ash, preferably barked. The simple process of stacks for the production of charcoal in forests has given place to automatic sectional furnaces, which give a better output and do not require specialised labour.

For railcars, the use of charcoal formed by the carbonisation of old sleepers from relaid lines is specially indicated. Sleepers, which are generally of hard, creosoted woods, free from waste and completely barked, when withdrawn from the permanent-way, provide the most suitable material for the production of an excellent charcoal. Railway managements have large stocks of them, the tonnage replaced annually on the French systems reaching 300 000 tons.

Carbonisation of sleepers in fixed furnaces was developed by M. Guillaume, Engineer of the Est Railways, who gave the name of « Geka » to the charcoal thus obtained. This charcoal is enriched by the presence of hydrocarbons produced by the distillation of the creosote remaining in the sleeper after about thirty years' service. The calorific value is about 8 000 cal./kgr. (14 400 B.T.U./lb.), the total carbon content reaches 92-93 %, the ash content is reduced to 2.4 % and the resistance to crushing amounts to 20 kgr./cm^2 (284 lb. per sq. in.).

We have already described, in *Le Génie Civil* of 9 May, 1936 and 7 August, 1937, the first railcars with charcoal gas producers, put into service by the former State and Est Systems. The operating results with these vehicles having been regarded as encouraging, the French National Railways Company ordered from Messrs. de Dietrich a series of three railcars with charcoal gas producers (fig. 1 and 7), of which the first two have been put into service in the Western Area (former State System).

These new vehicles, which benefit from the experience gained in working the two above-mentioned railcars, each comprise a body carried by bogies.

Body.

The body is 22.50 m. (73 ft. 11 in.) long and has (figs. 2 to 5) a driver's cabin at each end, two vestibules, a third class compartment with accommodation

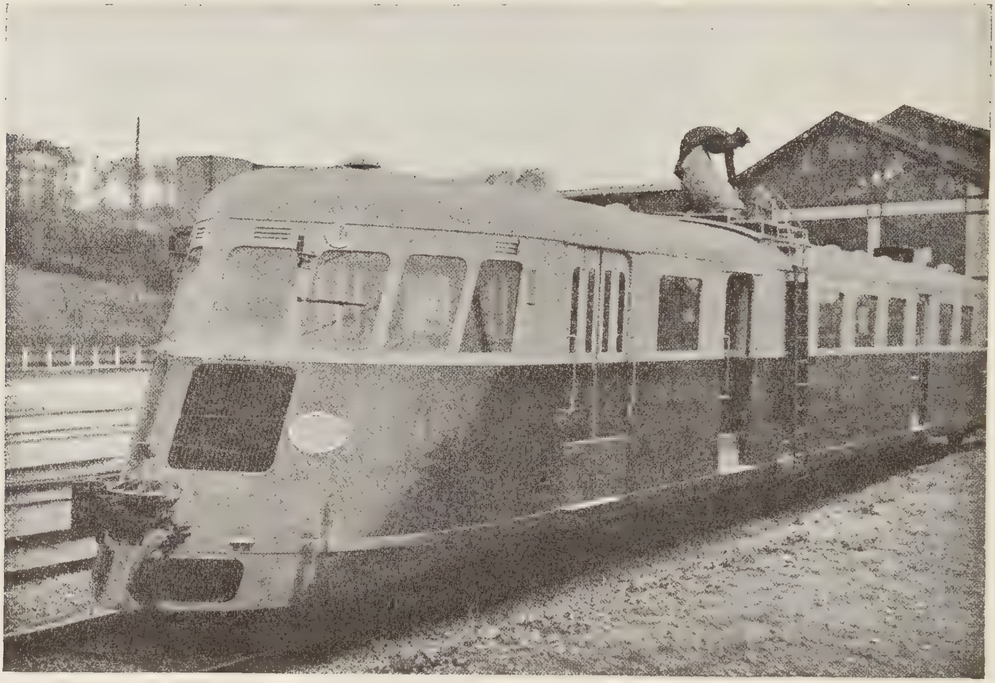


Fig. 1. — New de Dietrich railcar with charcoal-gas producer, French National Railways Company. — Loading fuel through the roof.

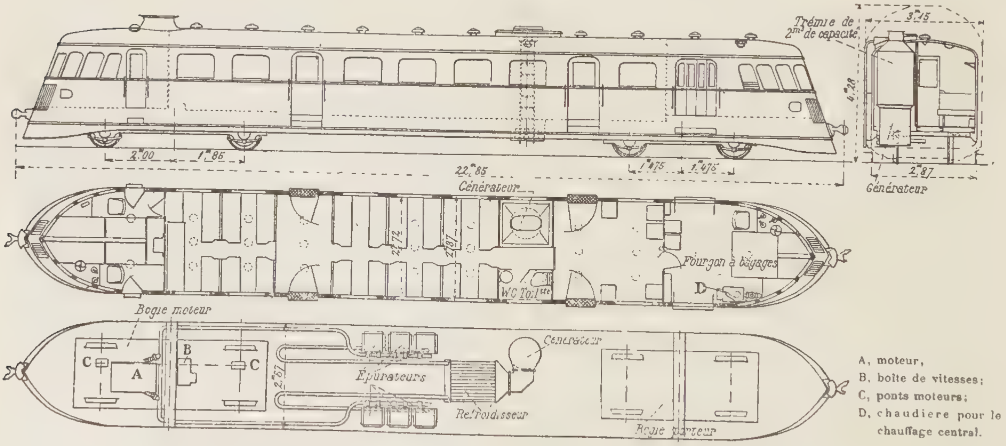


Fig. 2 to 5. — Elevation, cross section and horizontal sections of railcar.

Note. — A, engine. — B, gearbox. — C, transmission gear to axles. — D, boiler for central heating. Trémie de 2 m^3 de capacité = 70.6 cu. ft. capacity hopper. — Fourgon à bagages = luggage compartment. — Bogie moteur (porteur) = driving (carrying) bogie. — Epurateurs = purifiers. — Refroidisseur = cooler.

for fifty-four passengers sitting and forty-six standing, a lavatory and a luggage compartment capable of holding 1 000 kgr. (2 200 lb.). The car is heated by hot water from an independent boiler of welded plates, Dietrich system.

The body rests on two bogies, of which the driving one has a wheelbase of 3.90 m. (12 ft. 9 1/4 in.) and the carrying one a wheelbase of only 3 m. (9 ft. 10 1/8 in.). The wheels, of the monoblock type, are of chrome-molybdenum steel. The brake is of the Westinghouse self-regulating type. The total weight of the railcar is 32 t. (31.5 Engl. tons) empty, and 42 t. (41.3 Engl. tons) loaded.

Gas-producer.

The Panhard type gas-producer, with inverted combustion and without a nozzle, comprises three sections : the generator, which is placed in a vertical position towards the middle of the vehicle, the cooler, and the purifiers, which are situated under the body.

The *generator* is composed of two parts : the body and the hopper. The body, in which combustion takes place, is formed by two concentric shells. The internal shell is lined with carborundum fire-bricks, which are practically indestructible; the ashes are eliminated by means of an oscillating grate.

The hopper, which is placed above the body, has a capacity of 2 m³ (70.6 cu. ft.) and will hold 500 kgr. (1 100 lb.) of charcoal. Loading is accomplished through the roof with the aid of a mobile ladder. A deflector with a central aperture distributes the fuel to the required part of the firebox.

The air necessary for combustion is drawn in by the deflector and circulates about the charcoal feeding cone. This air has come in through the inlet of the ignition fan and has first circulated in the space between the refractory firebox and the outer wall of the gas-producer, which is thereby cooled.

To the hopper is fixed the starter (a jet, for starting and slow running) which is connected with the exterior by a pipe, closed by a non-return flap valve which prevents the flames being blown back.

The body of the generator protrudes beneath the floor of the car, with the result that the grate and gas outlet to the cooler as well as the grate and ash-pan inspection covers are rendered accessible from the outside by means of doors set in the side of the car.

The cooler, which reduces the temperature of the gas to about 100° C., (212° F.) is formed by a horizontal bank of 40 × 50 mm. (1 9/16 in. × 2 in.) tubes welded into two collectors. The input collector is connected to the generator by a large elbow and the output collector has two tubes from which two pipes lead into the purifiers.

The *purifiers,* six in number, are arranged in two groups of three in aluminium cases and function entirely dry. The gas passes through cotton cloths stretched on metal frames. The cloths are of a very fine texture and are kept in place by wire gauze elements. Woolly material is placed between the cloth and the wire gauze to prevent the two surfaces coming into contact with each other.

Before leaving each purifier, the gas passes through a safety-filter of very fine wire gauze, fastened between two coarser gauzes. This filter will only allow perfectly clean gas to pass; it would choke immediately if this condition were not fulfilled and this would stop the engine.

On leaving the purifiers, the gas goes to the engine through two pipes 90-95 mm. (3 9/16 in. to 3 3/4 in.) in diameter. Before reaching the engine, it passes through a mixer placed on the latter. This mixer mainly comprises a tube with two branches, one of which carries the gas and the other air; it automatically supplies the gas coming from the producer with the quantity of air sufficient to form the explosive mixture.

Engine.

The valveless engine is of Panhard design, and has twelve 140 mm. (5 1/2 in.) bore × 160 mm. (6 5/16 in.) stroke V type cylinders, the swept volume thus being 29.5 litres. The compression factor is 8 and the horse-power 280 at a speed of 1 750 r.p.m.

This engine is carried on the bogie with 3.90 m. (12 ft. 9 1/4 in.) wheelbase, and drives both axles through a gearbox with two output shafts.

Gearbox.

The gearbox is of the Mylius pre-selective type with gears always in mesh; it has five synchronised speeds and two output shafts. Force-feed lubrication is provided by means of a geared pump.

The two output shafts are connected through a differential which automatically counterbalances unevenness in the rolling paths of the two axles.

The reversing gear is incorporated in the box in order to facilitate the changing of the running direction and to lighten the construction of the transmission to the axles.

The clutch is of the plate type, the plates being moved by increasing the volume of an expanding box, one inner face of which is formed by a rubber diaphragm.

Figure 6 gives a section through the gearbox which, for simplicity, shows the four shafts in the same plane. Actually shafts I, II and III are in one horizontal plane, but the output shaft IV is situated below this plane.

The input shaft M, driven by the engine passes through the box to drive the clutch which drives the coaxial primary shaft I.

In one direction of travel, the drive is transmitted through primary shaft I, intermediate shaft II and output shaft IV.

In the other direction of travel, the drive is transmitted through primary shaft I, intermediate shafts II and III and output shaft IV.

In both directions of travel, the gear ratios are as follows :

1st, 4.91 to 1;
2nd, 2.765 to 1;
3rd, 1.82 to 1;
5th, 1 to 1.
4th, 1.31 to 1;

Reversing, declutching and synchronisation are performed by the action of compressed air, letting in the clutch and engaging speeds by the release of springs E and V.

Selection of speeds is controlled by a lever which turns shaft A and, through bevel gears C, the selector shaft S.

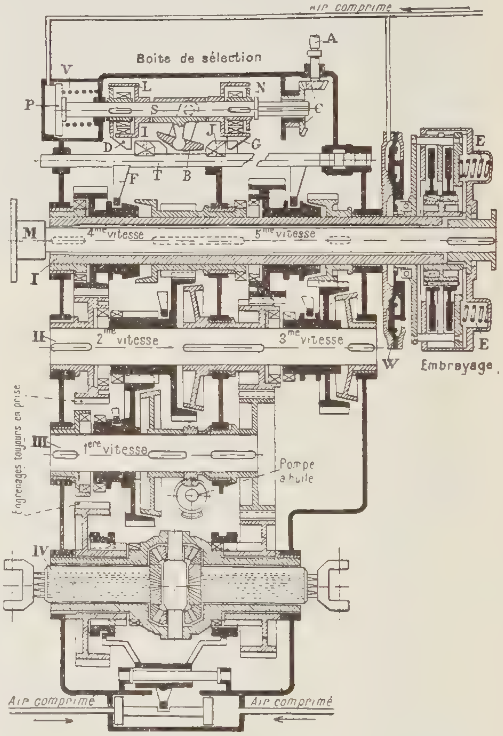


Fig. 6. — Diagrammatic section of gearbox.

Note. — Air comprimé = compressed air. — 1re (2me, etc.) vitesse = 1st (2nd, etc.) speed. — Embrayage = clutch. — Pompe à huile = oil pump. — Engrenages... = gears constantly in mesh. — Inverseur de marche = reversing gear.

Fig. 7. — Full-length view of de Dietrich railcar with charcoal-gas producer.

Engagement of speeds is facilitated by cone clutches which cause dogs of sliding gears and shafts to run at the same speed before the teeth engage.

Passage from one speed to another is made by a double movement of the sliding gears; first a movement to the right, bringing the clutch cone of the sliding gear for the selected speed into contact with a neighbouring clutch cone keyed to the shaft, which synchronises the speeds of sliding gear and shaft; then a movement to the left, which results in the dogs of the sliding gear engaging the corresponding dogs of the driving shaft.

Movement of sliding gears is controlled by forks F on rods T, which are shifted to the right by compressed air for synchronisation, them to the left by the spring V, for engagement.

Three operations have to be performed by the driver :

1. Selection of new speed,
2. Declutching and synchronisation,
3. Engaging new speed and letting in clutch.

Selection of the new speed is done by placing the speed-selection lever opposite the number of the chosen speed. This movement is transmitted to the selector shaft S, which rotates until the finger D in the springbox L comes opposite the catch I of the rod T controlling the new speed.

Declutching and synchronisation are performed by rapidly opening the compressed air control valve. The air reaches the rubber diaphragm of the expanding box W for operating the clutch. The pressure in this box increases and, through a thrust ball-bearing, compresses the springs of the main clutch, which is thus disengaged.

At the same time, the compressed air acts on the piston P of the selection box and moves the selector shaft S to the right. In this movement, the rocking lever B brings the rod controlling the previous speed to the rest position; the dogs of the sliding gear for this speed disengage, and the finger D of the springbox L draws to the right the rod T controlling the new speed, until the synchronising cones are in mesh.

Engaging the new speed and letting in the clutch are brought about by rapidly opening the air valve in order to open to the atmosphere the air pipe feeding the expanding box W and the selection box. This releases the pressure on the clutch diaphragm and on the piston P.

The selector shaft S then commences its movement to the left under the action of the spring V, and the finger G of the box N bears on the catch J of the rod T controlling the new speed; it draws to the left the sliding gear for this speed in engaging the dogs; the speed is then engaged.

When the pressure on the clutch rubber diaphragm falls sufficiently, the springs bear progressively on the clutch plates. This lets in the clutch.

Performance.

The maximum speed is 120 km. (75 miles) an hour. The speed of 118 km. (73.3 miles) an hour can be maintained on the level, and that of 87 km. (54 miles) on 1 in 100 gradients.

The average consumption of charcoal under full load is 0.410 kgr. (0.9 lb.) per H.P.-hour, corresponding to 1 kgr./km., or 3.55 lb. per mile, giving the railcar a range of 500 km. (311 miles).

The fuel used can be either « Geka », produced by the carbonisation of old railway sleepers, or ordinary charcoal.

The total time taken to light up the gas-producer, including the fanning period, is ten to fifteen minutes. To permit of movement in depots without lighting up the gas-producer, a small tank and carburettor have been fitted for petrol feed.

* * *

The use of producer-gas railcars is not contemplated for long runs at high speeds, such as Paris-Lyons, Paris-Vichy, Paris-Le Havre, which are performed at present by powerful petrol- or oil-driven railcars. On the other hand, they can be of great service on less important runs with many stops. They are naturally very suitable for use in the numerous forest regions of France, especially the South-Western Departments.

The putting into service of producer-gas railcars is still too recent to make the preparation of accurate cost data relating to maintenance and depreciation possible. In fact, the oldest railcar with gas-producer has only run 40 000 km. (25 000 miles) to date. Nevertheless, results obtained with stationary producer-gas engines lead to the belief that the life of producer-gas engines is no shorter than that of similar petrol engines.

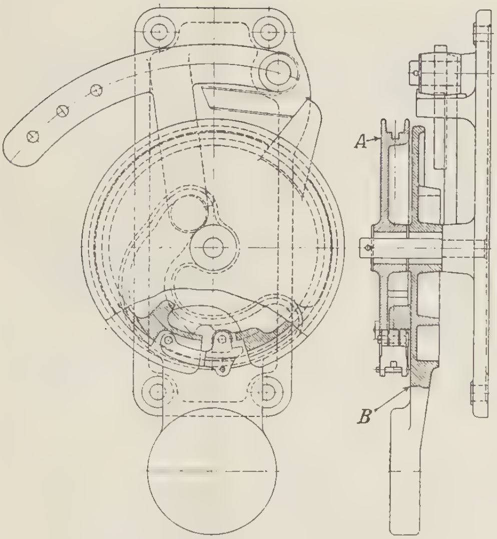
[656. 257 (.945)]

Double-wire signalling, Victorian Government Railways.

(*The Railway Gazette.*)

Double-wire transmissions for points and signals were first introduced on the Victorian Government Railways in 1926, but found little use until 1934, when much experimental work was carried out and further installations brought into service. Several improvements were made in the equipment, and signals are now being operated easily at distances up to 1 500 yards, and points up to 850 yards. Novel and interesting features are included in the new equipment, designed to overcome the disadvantages of that previously used.

With the earlier types of signal mechanism, a clear signal was liable to be improperly displayed in the event of the return wire breaking. The new mechanism was designed to overcome this by the use of a disengaging clutch mechanism illustrated in fig. 1. The new type of point machine simplified the layout of the equipment and increased the efficiency of operation, maintenance being considerably facilitated; new improved methods of mechanical detection were also adopted, the designs being suitable for both double- and single-wire working and having distinct advantages over the hatchet and slide types now widely used. These improvements, which have been patented, were designed by Mr. F. W. Harvey, Assistant Engineer, Signal and Telegraph Division.



FRONT VIEW SHOWING CLUTCH MECHANISM

HALF SECTION OF WHEEL & CAM PLATE

Fig. 1*a*.

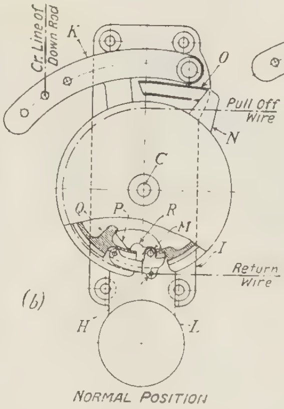


Fig. 1*b*.

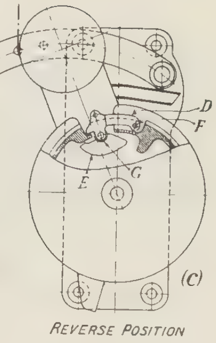


Fig. 1*c*.

Signal mechanism.

The signal mechanism is of the cam plate type and consists essentially of two elements, a grooved pulley wheel *A* (fig. 1, *a*, *b*, and *c*) and a circular cam plate *B*; these are capable of independent rotation about a common axis *C*, but can be coupled together by a releasable clutch mechanism *D* and *E*. They rotate in unison during normal operation, but are automatically uncoupled should the return wire break. The clutch arm *D*, located in the rim of the pulley *A* and pivoted at *F*, carries a roller *G* engaging under tension with a projection *E* on cam plate *B*.

The pull wire is connected to the clutch arm *D* at *H* and passes round the pulley; *A* and *B* are mounted on base plate *I*, movement being imparted to the signal through the crank *K*, one arm of which is connected to the signal down rod, while the other engages with the cam path on *B*. The crank *K* is also mounted on the base plate. If a wire breakage causes the pulley to rotate, disengagement of the clutch arm *D* with the projection *E* occurs owing to release of tension in the wire. If the signal is at « danger », the cam plate remains normal and maintains it so, but if the signal is at « clear » the balance weight *L* returns it to danger. The clutch arm *D* is kept in training on its pivot by a limited degree of radial movement each time the signal is operated. Roller *G* is normally set out of engagement with the notch *R*, as shown at *M*; the projection *Q* on the wheel holds the cam plate projection *N* against the stop *O* on the base plate. In normal operation idle movement of the pulley occurs until roller *G* engages in notch *R*, but on the signal being returned to danger it lifts out of the notch and assumes its normal setting.

In the event of the wheel becoming uncoupled from the cam through any cause other than a broken wire, the clutch is re-engaged by operating the hand lever from reverse to normal when the roller *G* rises over the ramp *P* to assume its normal setting.

The projection *Q* is provided to engage with the projection *E* on the cam plate, and prevent the cam being held in the reverse position when the wheel is operated to the normal.

Point mechanism.

This was designed to facilitate ready inspection, adjustment and maintenance, and reduce to a minimum the idle travel in the transmission between the withdrawal of the plunger and the movement of the point blades. Simplification of associated mechanisms and connections is also obtained.

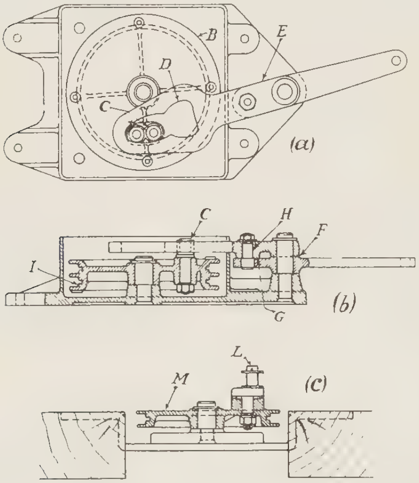


Fig. 2.

Figs. 2*a* and *b* give a plan view with cover removed, and a central transverse section of the motion wheel, shown in its central position with operating rollers engaged with the cam. The case is of cast iron, fitted with a sheet steel cover. Motion wheel *B* carries on its upper face a pair of concentrically-aligned rollers *C*, which engage with the cam slot *D* in one end of the crank arm *E*, itself divided as shown at *F*, its two sections being connected at *G* by a shear pin *H* to avoid damage to the mechanism should the points be run through. Inspection and maintenance are readily effected without removing the motion wheel or disturbing the transmission wires. The reduction in idle travel was obtained by using a pair of rollers and suitably shaped cam, instead of the one roller generally used with this type of movement.

Wheel *B* has a double groove in its rim, groove *I* being used when points and lock bar are operated by a single lever, and motion transmitted through a chain to wheel *K* (figs. 3*a* and *b*), which in turn operates the lock bar and plunger, usually by means of connecting rods and cranks. In an alternative arrangement a motion wheel *M*, fig. 2*c*, may be used in place of the crank to control and operate the lock bar. Movement of the latter is then effected by chain drive from wheel *K*, its rim having a second groove for the purpose. Adjustment of lock bar travel is provided for by an adjustable eccentric stud *L*.

When a lock bar is operated by a separate lever, the transmission wires are connected directly to wheel *K*.

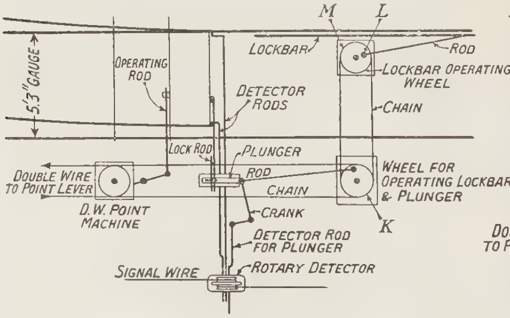


Fig. 3*a*.

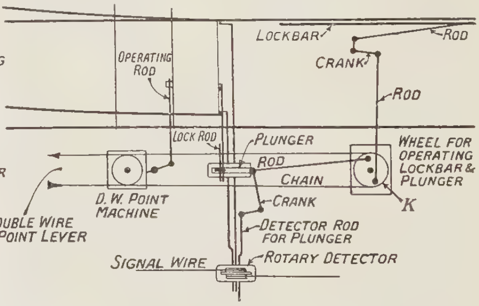


Fig. 3*b*.

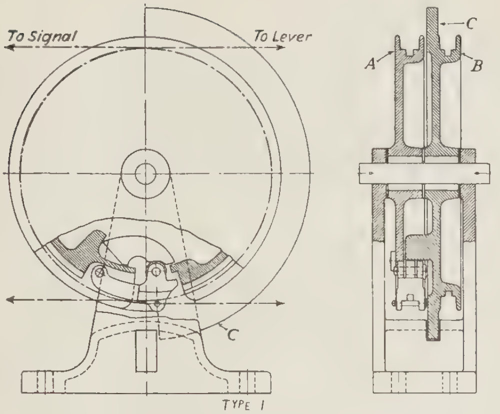


Fig. 4a.

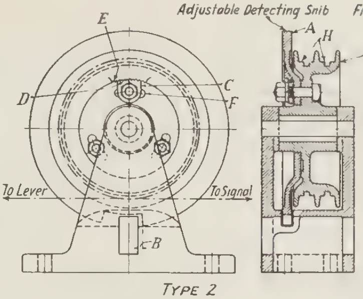


Fig. 4b.

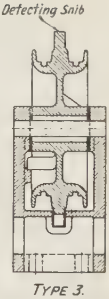


Fig. 4c.

Mechanical detectors.

To overcome detection difficulties in double-wire transmissions due to temperature variations, new designs of detector have been prepared to suit varying conditions. Type 1 (fig. 4*a*) consists of two pulley wheels coupled together in the same manner as the pulley and cam plate of the signal mechanism, and mounted vertically on a base through which the detector blades from the points pass transversely. Pulley *A* is similar to pulley *A* of the signal mechanism, but *B* is a grooved wheel, with a detecting snib *C* cast on its inner edge.

Type 2 (fig. 4*b*) consists of a pulley wheel *G* having two grooves *H*, carrying a detecting snib *A*, capable of adjustment around the wheel for varying clearance *B*. The snib is held in position by plate *C*, which has serrations *D* engaging with others, *E*, on the snib face. Slotted holes *F* allow of circular movement on the wheel.

Type 3 (fig. 4*c*) is a modification of type 2, and has a snib solid with the wheel.

Conditions vary according to whether : *(a)* The signal is a long distance outside

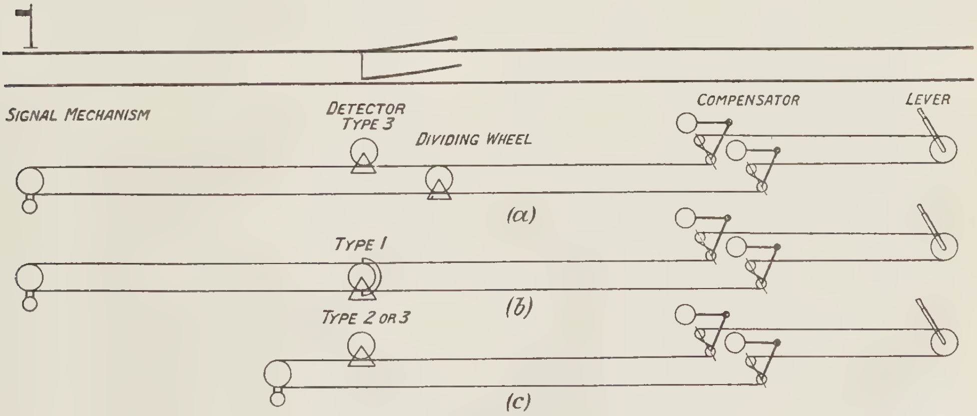


Fig. 5.

the points; or *(b)* the signal is close to the points.

In case of *(a)* temperature variations may alter the adjustment of the detector so that the points become locked. This is overcome by dividing the double-wire signal transmission at the points, so that the compensator does not act on the portion between the points and the signal. A dividing wheel similar to Type 1 detector, with the exception that the detecting snib is omitted, is placed close to, and on the lever side of, the detector. Type 3 detector is then used, connected as shown in fig. 5*a*. Alternatively, the dividing wheel may be combined with the detector as a complete unit. Type 1 detector is so designed, and applied as in fig. 5*b*. The disengaging clutch mechanisms on the dividing wheel and detector are provided to ensure a danger signal being exhibited should a wire breakage occur between the lever and detector, or lever and dividing wheel. Types 2 and 3 are also used when the signal lead is not divided (fig. 5*c*), while type 2 can be used, within limits, when the signal is placed some distance outside the points and the lead is undivided. By increasing clearance at *B* some movement may be imparted to the detector without locking the points, its amount being governed by the normal idle travel in the signal mechanism. The clearance will be a maximum at low temperature, but must not be sufficient to permit of the signal being moved if the points are not properly set.

[**62**. (01 (.73) & **721. 1** (.73)]

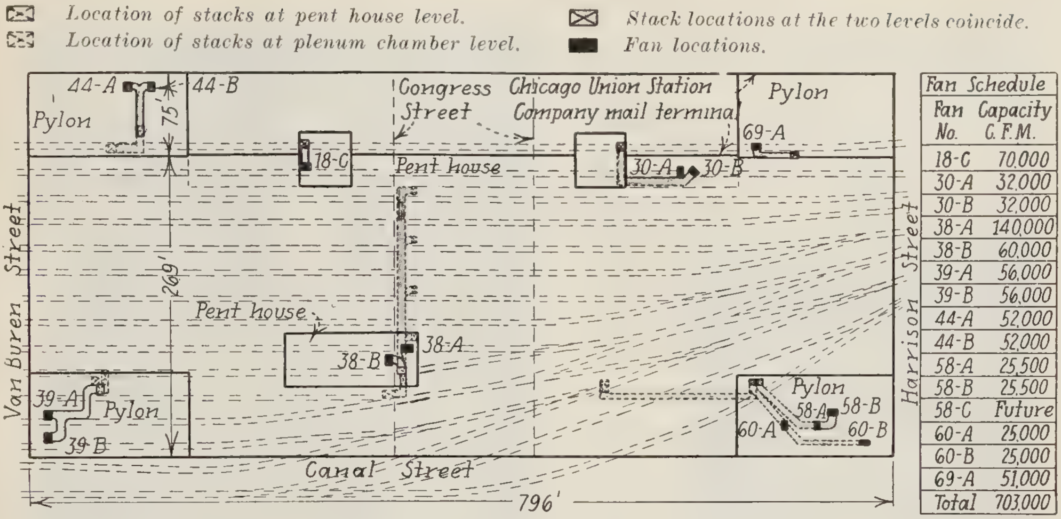
Building above steam operation presents problems.

(Railway Age.)

Experience at large post office over tracks at Chicago Union Station shows the destructive effect of smoke and gases on materials and equipment.

That the removal of large volumes of locomotive smoke and gases from confined areas presents a difficult problem, from the standpoint of both the mechanical exhausting equipment and the effect of the smoke and gases on metals and concrete, has seldom been demonstrated more conclusively than at the United States Post Office building which extends over the tracks at the Union Station in Chicago. Here the smoke and gases from as many as 2 000 train movements a day are collected in a chamber above the tracks and then carried to the roof of the building through exhaust stacks. In this installation approximately four years of service had brought about the accumulation of approximately 750 tons of cinders and soot sludge; unusually severe corrosion of the reputedly corrosion-resistant metal floor hangers and the exposed parts of the mechanical exhaust equipment; and the deterioration of much of the concrete fireproofing of the structural members.

In 1936, upon the discovery of these conditions, work was started to remedy them. In the work which followed, and which was completed only recently, all of the cinder and soot sludge was removed from the plenum chamber and 6 670 of the rod floor hangers were replaced by specially protected rods of a less expensive character. In addition, a new multiple-pitched, water- and acid-proof floor was provided throughout the smoke chamber over an area of approximately 163 000 sq. ft., overhauled and increased in efficiency and capacity.



Fan Schedule	
Fan No.	Capacity C.F.M.
18-C	70,000
30-A	32,000
30-B	32,000
38-A	140,000
38-B	60,000
39-A	56,000
39-B	56,000
44-A	52,000
44-B	52,000
58-A	25,500
58-B	25,500
58-C	Future
60-A	25,000
60-B	25,000
69-A	51,000
Total	703,000

Sketch plan of the Post Office building over the station tracks, showing the exhaust stack and fan locations.

Original exhaust system was inadequate.

The post office building, built in 1931 and 1932, is a 12-story structure, 796 ft. long by 344 ft. wide, which lies directly south of the Union Station building, length-wise over the 14 diverging tracks which enter this station from the south. In the arrangement provided for disposing of the smoke and gases emitted beneath the building, a plenum chamber was constructed continuously beneath the first floor level, with a 4-in. reinforced concrete floor so located as to provide a minimum clearance of 17 ft. above the top of rail. This chamber, in which the smoke from engine stacks is collected through longitudinal cast iron troughs directly above the tracks, is exhausted at the roof level of the building through eight exhaust stacks, located marginally along the sides of the building. The chamber has a floor area of approximately five acres, and, owing to the irregularities in the level of the first floor above, and to the structural members which extend into it, has a honeycombed roof of limited height, which has seriously restricted the free movement of the smoke and gases to the exhaust stacks. Of importance also in the matter of the rapid ventilation of the plenum chamber, is the fact that the exhaust stacks were located with greater regard to the saving of valuable floor space within the building than to the particular requirements of a most effective exhaust system.

Another feature of the original construction that proved to be unsatisfactory was that the floor of the plenum chamber was laid practically level, which did not permit ready run-off of condensation collected, even though a number of drainage outlets were provided. Still other features in the design of the exhaust system which proved inadequate were the capacity of the ventilating equipment and the character of the steel used in the rods which support the floor of the plenum chamber. The ventilating equipment was designed apparently to take care of normal average conditions, but failed to take into consideration the rapid reduction in the efficiency of the equipment under the conditions imposed. The greatest care was exercised in the selection of the material to be used in the plenum floor hanger rods, both as regards its corrosion-resisting qualities and high tensile strength, but, under the conditions which prevailed within the chamber, the material selected, with a 14 per cent chromium content and a tensile strength of 98 000 ft. per sq. in, offered little more resistance to corrosion than might be expected of ordinary steel under less severe conditions, and proved to have an ultimate tensile strength, after fabrication, far below that which has been expected.

Condensation was troublesome.

As a result of the conditions outlined, the smoke removal system has been far from satisfactory in operation. In the first place, the combination of the restricted and broken areas within the plenum chamber and the inadequate capacity of the ventilating equipment did not permit freeing the track area of smoke as quickly and effectively as had been hoped for, especially on days of relatively low atmospheric pressures and high humidity. At the same time, the installation failed to create sufficient velocity of the smoke and gases in the plenum chamber, resulting in excessive condensation both within the chamber and on the under side of the chamber floor. As a result, large quantities of moisture accumulated within the chamber, where it combined with cinders and soot to form a heavy wet sludge, while that which precipitated on the under side of the chamber floor dropped to the track and platform levels to keep them wet almost constantly, presenting a condition which was particularly undesirable during the winter, with the formation of ice which resulted.

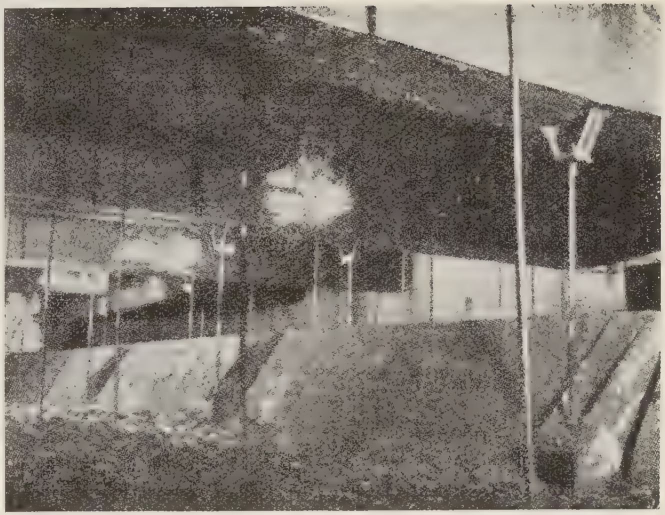
The floor of the plenum chamber was supported from the structural members of the floor above by approximately fourteen thousand 3/4-in. chromium-steel rods, which were screwed into cast iron inserts embedded in the concrete of the first floor and into special brackets encased in the concrete of its own floor. Similar rods supported the cast iron smoke troughs above the tracks. These rods, according to laboratory tests before they were installed, showed a high degree of corrosion resistance and a factor of safety relative to the weight carried of approximately 20 to 1.

Investigation disclosed serious conditions.

The serious conditions existing as regards the smoke exhaust system were first brought to light during June, 1934, with the initial discovery of severe corrosion of a number of the exhaust fans. Detailed inspection of the conditions within the plenum chamber was at first impossible because of the accumulation of sludge within this area, which ranged from 6 to 16 in. in depth, covering the lower ends of the floor-supporting rods and completely choking the relatively few drainage outlets which had been provided. So far as the plenum chamber itself was concerned, therefore, the first problem was to remove the sludge accumulation. Because of the quantity of material involved and the almost continuous occupancy of many of the station tracks, this presented considerable difficulty. However, a night crew was organised for carrying out the work, and, between midnight and 8 a. m. over a period of several weeks, the sludge was shoveled through the openings of the smoke troughs directly into gondola-type cars below.

As the sludge was removed and the bottom of the rods supporting the chamber floor were exposed, it was found that the corroded condition of these rods was generally more serious than had been anticipated. In some cases 11 of the 12 rods supporting separate bays were entirely eaten off and the slab was being carried entirely by the 6-in. lip of the cast iron smoke trough. It was found further that many of the rods and rod clamps supporting the smoke troughs had corroded through, and that a considerable part of the concrete fire-

The Post Office building, 796 ft. long by 344 ft. wide, extends over 14 tracks.



In four years, approximately 750 tons of cinders and soot sludge had accumulated in the plenum chamber.

At the track level, looking through the large area beneath the Post Office building.

proofing of the structural floor members within the chamber had been affected seriously due to one cause or another. Still another observation which caused concern was the fact that, in addition to the rods and clamps which had failed entirely because of corrosion, many of the rods and clamps were broken, even where there was sufficient cross section remaining to support the load imposed under normal conditions.

Early during this preliminary inspection it became evident that there was serious danger of large sections of the plenum chamber floor collapsing. Therefore, immediate steps were taken to prevent this. First, an emergency inspection was made of the entire chamber; tracks were taken out of service, even during rush-hour periods, where necessary; and the floor slab and smoke troughs were supported where required by shoring until temporary supporting rods could be installed within the chamber.

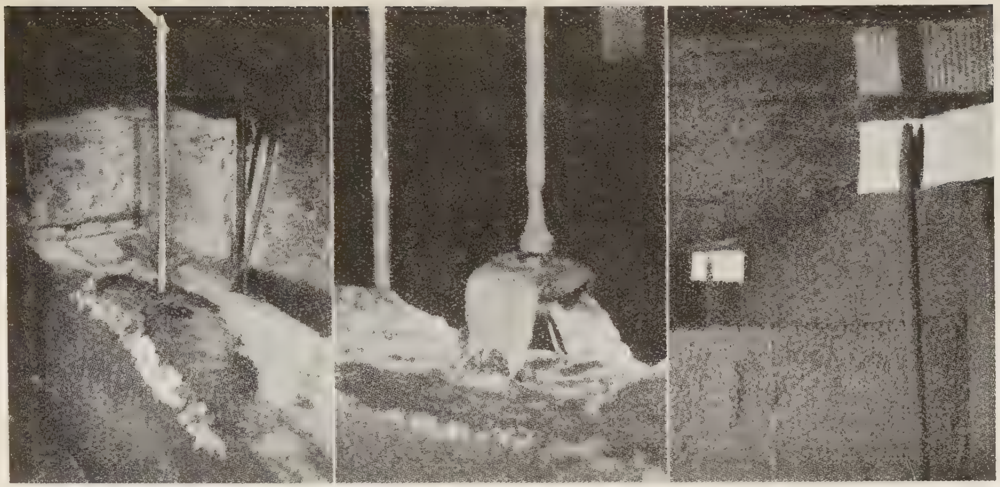
While this emergency work was under way, laboratory examinations were made to determine the specific causes of the failures of the chromium-content rods and brackets, particularly those failures which involved the breaking of the rods and brackets where there still appeared to be sufficient cross section to support the loads carried. These examinations showed the grain structure of the metal at the breaks to be highly crystallized, a condition which was determined to be the result of the heating of the rods during their fabrication to meet the peculiar installation requirements. Many of the specimens examined were found to have a tensile strength of only approximately 26 000 lb. per sq. in., as compared with their rated strength of 96 000 lb. per sq. in. at the time of their installation.

As a result of the disclosures in these investigations, it was decided to change out all of the rods and brackets supporting the smoke troughs, and every other slab-supporting rod, regardless of its condition, in addition to all rods that had lost in excess of 25 per cent of their original cross-sectional area. This resulted in the necessity for changing out 6 670 rods, instead of approximately 2 000 as was anticipated originally. As a further result of the investigations, it was decided to use in replacement, 3/4-in. rods of S. A. E. x-1335 steel, which has a tensile strength of 80 000 lb. per sq. in., and to protect these rods against corrosion by a special encasement.

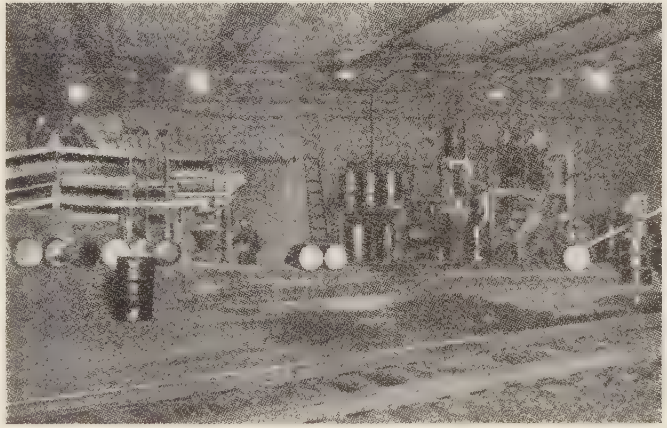
Several methods of replacing the old rods with the new ones were considered, but the method finally adopted was, first, to cut off the old rod about six inches above the floor slab; then to unscrew the upper section from the insert bracket in the ceiling; and then to drive the lower end down and completely out through the bottom of the floor slab. The new rods, with flat cast-iron plates on their lower ends, were inserted in the holes in the floor slab left by the removal of the old rods, and were screwed into the original inserts in the concrete slab above. Since all of the inserts had right-hand threads, the new cast iron plates at the bottoms of the rods were tapped with left-hand threads so that through turn-buckle action the proper tension could be put in each of the rods as installed.

Before inserting the new rods, the end portions to be encased in the slabs at both top and bottom were given a protective coating of mineral rubber compound, and, after installation, the holes in the concrete were filled completely with a fine cement grout. In replacing the trough-supporting rods, all of the beam clamps used previously were abandoned because of their crystallized condition, and the new rods were given a threaded connection into holes drilled in the structural floor members above.

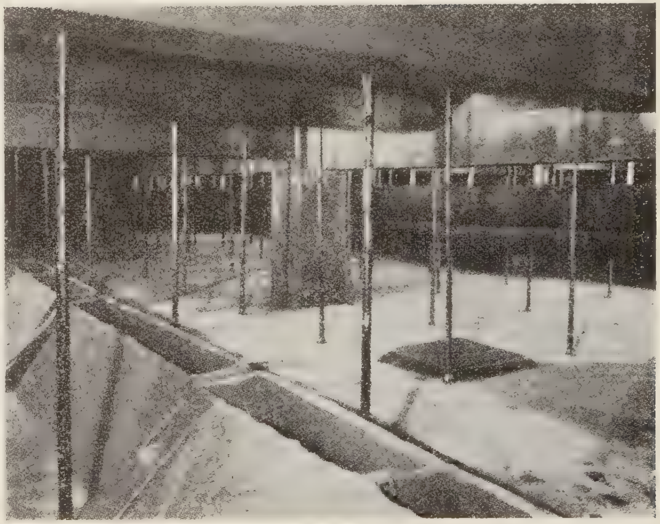
Simultaneously with the installation of the new hanger rods, consideration was given to the problem of protecting them against the severe corrosive con-



Left — Plenum chamber floor-supporting rods, corroded completely through. Center — Many of the smoke through-supporting brackets were seriously affected. Right — Large areas of the concrete fire-proofing of the structural members were bulged or entirely broken away.



All of the mastic for the new floor within the plenum chamber was placed by air pressure from a central mixing plant at the track level.



A section of the plenum chamber after the work of cleaning, paving the floor, and renewing rods had been completed.

ditions which had so quickly and seriously affected the original rods. The method finally adopted consisted of encasing the rods throughout their length with a special plastic compound, held in place by means of wood pulp casings, similar to the fibre duct commonly used for underground cable installations, but split longitudinally into two halves for application purposes. The plastic compound employed consisted of 80 per cent Wurtzilite and 20 per cent Tung oil (Chinawood oil).

Since one of the fundamental defects in the original design of the plenum chamber appeared to be the lack of pitch for drainage of the floor, and an insufficient number of drainage outlets, it was decided in the repair work to resurface the entire chamber floor area with a water- and acid proof material, with a multiple-pitched surface to insure quick and complete drainage of the moisture that would be collected. After much experimentation, in which small sections of the floor area were covered with a wide variety of plastic mixtures, a material of the following mix was decided upon and was used over practically the entire floor area :

1 part Portland cement,
3 parts emulsified asphalt,
5 parts Waylite (coarse),
3 parts Waylite (fine),
3 parts Vermiculite.

This material, which weighed only 62 1/2 lb. per cu. ft., had sufficient structural strength for foot traffic, and gave indication under test of being both waterproof and resistant to acid attack. All together, 152 970 sq. ft. of new floor surfacing was laid within the chamber, the material being applied to depths of 1 to 9 in. in order to insure adequate drainage slopes.

Determining the most effective and economical manner of applying the floor surfacing material presented almost as much of a problem as the selection of the material itself. Several methods of carrying out the work were considered and tried out, but the method adopted as the most practical and economical involved the use of a cement gun. Even this method, to be entirely satisfactory, required some adjustment from ordinary practice because of the tacky character of the material to be handled.

The final arrangement of the placing equipment provided for the location of the aggregate mixing plant and the cement gun, together with the liquid asphalt supply, in an area along one side of the track layout, and then forcing by air pressure the mixed dry aggregate and the asphalt through separate hose lines to the working area within the plenum chamber. Here, these materials were mixed within the cement gun nozzle as they were applied to the floor. In spite of the fact that the materials were conveyed distances up to 700 ft. by this method, no difficulties were encountered, and it was possible to place an average of approximately 85 cu. yds. of the flooring material each eight hours of working time.

Much concrete work repaired.

Another important phase of the work required within the plenum chamber was to repair the concrete fireproofing which encased the structural members of the first floor of the building. This fireproofing was supposedly two inches thick and its original design called for adequate wire mesh reinforcing to insure its adherence to the steelwork.

Inspection of the fireproofing showed a large percentage of it to be in a condition that was far from satisfactory. At many of the beams and girders the fireproofing actually sagged from the steel, while at hundreds of places, a hollow sound upon tapping indicated that there were air pockets between the concrete and the steelwork. At numerous places also, sections of the fireproofing had fallen entirely away from the steelwork, exposing the structural members. One of the rather surprising aspects of condition of the fireproofing was that, except in those areas directly above the smoke troughs, the concrete appeared to be little affected by the abrasive action of locomotive blast or by the acid conditions which existed within the chamber.

In view of the extent of the bulging fireproofing, it was considered advisable to repair only the worst conditions, leaving the remainder to be repaired as the situation may warrant in the future. In the work carried out, several methods were employed, depending upon the conditions found. On many of the beams where, because of the amount of the concrete involved, the sagging fireproofing appeared to be dangerous, it was drawn back tightly against the steelwork by means of tap bolts equipped with large cast iron button-type heads, which were turned up into holes drilled and threaded in the flanges of the members. At other points, where the fireproofing had fallen away completely, repairs were made by the Gunite method.

Over those areas of the fireproofing directly above and adjoining the smoke troughs, where, in some locations the concrete had been worn away by erosion as much as one-quarter inch, repairs were made by the Guntex method. This involved first, the application of an emulsified asphalt prime coat by means of an air gun, and then the application of a finish coat consisting of 80 per cent silica sand and 20 per cent emulsified asphalt, also by the air gun method.

In the work on the concrete fireproofing, 19 acres of concrete ceiling, wall and beam surfaces were washed and cleaned; approximately 1 500 patches were applied by the Gunite method; the reinforcing beneath the bottoms of 17 beams or girders was entirely replaced; and approximately 111 900 sq. ft. of the fireproofing and ceiling areas was Guntexed with asphalt compound.

Additional drains provided.

Other important items of work carried out within the plenum chamber included the repair of the existing 27 floor drains and the installation of 157 new floor drains; the installation of 192 additional manhole openings in the plenum chamber floor; and the installation of a supplementary chamber exhaust system near the center of the building to overcome a particularly severe condition of stagnation at this point. In addition to these changes and improvements, a system of high-pressure hot-water hose cleaning was installed within the chamber, whereby its entire interior can be flushed out periodically through the floor drains.

The installation of the many additional drains in the plenum chamber floor raised the problem of protecting them against freezing during severe winter weather, to prevent the accumulation of soot sludge within the chamber and possible damage to the drainage system. In solving this problem, gas-burning jets were installed at the lower ends of 72 drains where it was known that the condensation run-off would be the most continuous and severe. In addition also, especially in those areas subject to particularly drafty conditions, the drain pipes were wrapped with wool felt jackets, whereby it is expected that considerable saving will be effected in the operation of the gas burners, restricting their use to periods of only the most severe weather.

Ventilating capacity increased.

Along with the extensive work required within the plenum chamber itself, was the problem of repairing and increasing the capacity of the ventilating equipment carrying the smoke and gases away from the chamber to the atmosphere at the roof level. The mechanical ventilating equipment provided originally included 15 rotary-type fan units with theoretical exhausting capacities ranging from 22 500 cu. ft. per min. to 84 000 cu. ft. per min., and with a combined capacity of 562 000 cu. ft. per min. It was obvious, however, that as a result of service, this equipment was not operating to anywhere near its rated capacity, and had suffered severe deterioration from corrosion.

To check the efficiency of the equipment, and, as a basis for improving the ventilating system as a whole, hundreds of air movement readings with anemometers were taken throughout the track level area beneath the building. In this work, 183 reading points were established, and the tests involved extended over a period of several weeks. During this period, all dead air areas were plotted, which provided a basis upon which to work out improvements in the exhaust system. It was largely as a result of this extensive study of draft conditions about the track area that two supplemental exhaust arrangements were provided, one near the center of the building, as already mentioned, and a second near one corner of the building, where use could be made of facilities provided in the original design of the building for exhausting the motor vehicle gases at a large tailboard area.

In addition to these supplemental installations, all of the existing ventilating equipment was completely overhauled and repaired, which increased its efficiency in some cases as much as 100 per cent. At the same time, the ventilating efficiency at several points was increased by the substitution of larger units, with the result that in the improved ventilating system as a whole, there are now a total of 18 exhaust fans, with a total theoretical capacity of 737 000 cu. ft. per min., as compared with an estimated working capacity of the original units in their deteriorated condition of only approximately 300 000 cu. ft. per min.

Along with the enlarging of the capacity of the ventilating system, all of the rotors of the fan units were repaired and were given a shop coating of metallic lead. At the same time, all new metal ducts within the system were lead-lined, as were also replacement sheets in the hoods over the exhaust shafts at the roof level.

Work handled by Union Station Company.

The extensive work described was carried out over a period of approximately two years, and, as might be expected under the conditions outlined, involved phases of work which were both difficult and hazardous. Especially during the early inspection and repair work, it was essential that every man be equipped with a gas mask. Later, a system of bulkheading was devised whereby working areas were cut off from the remainder of the plenum chamber and forced ventilation provided which permitted working without masks. Fresh air ventilation for the working areas was provided by three electric-driven blowers, each with a capacity of 3 000 cu. ft. per min., which were mounted on trucks at the platform level and connected to the bulkheaded areas with Ventube flexible ducts.

All of the work involved in repairing and enlarging the capacity of the smoke exhaust system was carried out at the expense of the Federal Government under its agreement with the Union Station Company for the provision and maintenance of an adequate smoke exhaust system above the station tracks, and was done under the general supervision of William A. Richardson, senior maintenance engineer of the United States Treasury department. The actual work, however, was done under contract by the Chicago Union Station Company, which acted as both engineering consultant and general contractor. The plans and specifications for the work were prepared under the direction of O. H. Frick, general manager and chief engineer of the Chicago Union Station Company, and C. E. Cox, assistant chief engineer, while the actual work operations were carried out under the immediate supervision of William Landess, construction superintendent.

[625. 17 (.73)]

MISCELLANEOUS INFORMATION.

1. — The maintenance of line and surface to meet present-day operating requirements (1).

(Railway Engineering and Maintenance.)

American railroad history is a record of continuous achievement over more than a century, but progress in the last five years has probably been more spectacular than during any similar period in the life of the industry. An outstanding development has been the increase in train speeds, which, while appealing to the travelling and shipping public alike, has multiplied the problems confronting maintenance men. Freight trains are now scheduled almost twice as fast as they were prior to 1930, while passenger speed limits of 80 miles per hour with standard equipment and up to 100 miles per hour with special light weight equipment, have become rather commonplace.

Operating requirements may vary from year to year but today, more than ever before, emphasis is placed upon economically maintaining a railroad suitable for these higher speeds, with perfect safety. This aim is being realized, for in the face of declining revenues and drastically curtailed maintenance expenditures, faster trains are being run with a higher standard of passenger comfort than ever previously existed.

The committee report delivered before this convention in 1936 on preparing and maintaining track for high speed operation, fully covered the details surrounding the half-dozen super-speed trains then in service. Since that time the number has increased many times, and such trains are now operating from one border of the country to another. Your committee, in order to obtain data showing the influence of these changes on track maintenance, submitted a questionnaire to various association members, and received replies covering nearly 50 000 miles of all classes of track. The information contained therein is presented in the belief that it reflects practices and methods in effect on a typical cross-section of our railroads today.

Modern schedules—A factor.

Consideration of certain factors directly influencing maintenance may be appropriate here. It is conceded that the light-weight diesel-powered trains and the specially designed high-speed locomotives have little adverse effect on good track, at the 90 or 100 miles per hour speeds for which they are constructed. However, motive power built for the requirements of years gone by is being called upon to move standard equipment, both passenger and freight, at speeds far above those for which designed.

One such locomotive exceeding critical speeds may cause track damage that will require days or weeks to correct; hence, uniform and reasonable schedules that will permit recovering a slight amount of lost time without extreme bursts of speed are essential.

Slow running is inevitable around terminals, but every permanent intermediate restriction must be considered as a definite source of delay and studied with a view to its removal, or modification to permit the highest possible speed. Improvements that will permit raising several such restrictions five or ten miles per hour will frequently mean that an otherwise difficult schedule may be fulfilled with ease and comfort. Temporary slow orders on ballasting or construction work can be dispensed with, but if it is necessary to close up during working hours for full speed, gang output may be reduced as much as one-third. The ideal schedule will provide some slight latitude for an occasional slow order, but these must be widely spaced and used with the utmost discretion.

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(1) Committee report presented to the 53rd Annual Convention of Roadmasters and Maintenance of Way Association (Chicago, September, 1938).

Restricting curves breaking up long stretches where continuous top speed would otherwise be possible, are being flattened as rapidly as finances will permit. Earlier methods of calculating the economic worth of curve reduction are not always followed, as the intangible value of passenger comfort may be the deciding factor. Roads reporting comprehensive curve revision programs are reducing to the maximum degree which they feel can be elevated for unrestricted tangent speed, usually about 90 miles per hour. Some roads maintain that this means going to 1-degree curves, while others feel that a 1 deg. 30 min. maximum is satisfactory. The type of equipment must be considered, as the light-weight trains with their lower centers of gravity and improved springing are comfortable on a given superelevation, where standard equipment at the same speed will produce a sense of crowding. The latter is therefore often operated at speed limits five or ten miles per hour below those set up for the light-weight equipment.

Grade conditions permitting, the amount of superelevation is governed by the degree of comfort desired, and certain standards tried out in 1935 have since been found inadequate. Roads at that time preparing for 90 miles per hour by placing 2 1/2 in. in 1-deg. curves, soon learned that this was insufficient, and after adding an inch, which produced the desired riding comfort at that speed, have discovered that the curves now hold elevation and stay in line, much more uniformly than before. Elevating one degree curves 3 1/2 in. is now most common, while one large system reports using 4 in. in anticipation of 100 miles per hour speed. A number of roads favor 5 in. or 5 1/2 in. superelevation for 90 miles per hour on 1 deg. 30 min. curves and for 80 miles per hour on 2 deg. curves. One railroad limits elevation to 3 1/2 in. on any curve, reducing speed accordingly; several use 5 in. and many 6 in. as the maximum permitted.

Easements.

The belief that runoffs should be made at the rate of about 1 1/4 in. per second of rise is almost universal, and for the speeds mentioned above will therefore vary from 320 to 470 ft. in length for 1-deg. curves, and up to 560 ft. for 2-deg. curves elevated six in., approximately the A.R.E.A. standard adopted in 1933.

Full elevation must obtain at the point of full curvature, continuing uniformly around the simple curve. Almost equally important, the spiral should be as long as the runoff so that the relation between curvature and elevation will be exactly the same at every point on the spiral. Earlier methods of using short spirals to reduce track shifting and running part of the elevation out on tangent, are not conducive to smooth riding or easy maintenance, and the practice is discouraged. One-degree curves shorter than about 260 ft. between spirals will not be entirely comfortable at 90 miles per hour, as the time interval between elevation run-in and run-out will not permit the necessary body adjustment. Usually these can be reduced to 30 or 45-min. curves with little work at slight expense, and will then ride nicely.

Alinement.

String lining and the transit are each advocated as being the proper medium for obtaining the true curve alinement so necessary with high speed. Several forms of string lining are in favor, from those used by the alert foreman for lining out the flat spots and pulling in the elbows, to the more intricate systems best utilized by the engineering corps, which provide a uniform curve and true spirals, at some increase in the amount of track work involved. A combination of transit and string methods is reported as being well suited to the rapid conditioning of an entire line for increased speed. Several roads use the transit only, setting permanent monuments at control points to aid in future restaking. Fast traffic distorts curve alinement, necessitating frequent checking, and the important thing is to have easily available some means of correction that is definitely superior to lining by eye alone.

Greater refinement is fully as desirable on tangent as on curves. Tangent track only slightly out of line will be noticeable at 90 miles per hour. Much out-of-face lining was done in preparation for fast schedules, and it is customary to set line stakes, or use a lining instrument in connection with ballasting work. No routine job of smoothing track may be called complete, if small line irregularities are allowed to remain.

Variations in gage are magnified as speed increases, and too much stress cannot be placed upon laying rail to truly uniform gage, which the use of the mechanical adzers has simplified, and upon correcting any irregular gage in connection with ordinary maintenance work. One or two roads have laid rail to 1/8-in. tight gage, in an effort to improve riding conditions. In this connection, it may be mentioned that cylindrical tread wheels on high speed equipment tend to reduce the objectionable whipping on tangents, which is sometimes present with cone treads.

Improvements for high speed.

Few roads report greatly augmented programs for replacement with heavy rail solely because of shortened schedules; yet nowhere is the effect of the stiffer rail section more apparent in improving riding qualities than under the very fast trains. A rather formidable mileage of 90-lb. rail remains in track carrying trains at 80 or 90 miles per hour, but it is being replaced with 112-lb. or heavier, as rapidly as the money is available. Special construction, such as continuously welded rail, special tie plates with hold-down devices, special joint plates and the like, all tend towards reduced maintenance, but their ultimate economy will be determined largely by local traffic conditions.

Increased activity in improving worn joints is quite general, as chipped or battered rail ends and bent or worn bars, coupled with ballast that is inclined to whip or puddle, must be corrected by welding and renewal with bars designed to compensate for rail wear, before suitable riding conditions can be obtained.

Minor sags or humps in the grade line, not objectionable a few years back, must now be smoothed out. Uniform cross level is essential, and rigid insistence on the use of the level board in spotting up, both on curve and tangent, is recommended.

Increases in standards of depth of ballast section are reported, and widening of the ballast shoulder on tangent and curve is shown to be rather general, as an aid to holding line and surface. Light ballast may call for replacement with more stable material because of its tendency to whip out under high speeds. All replies show that mechanically tamped track is far superior to that put up by hand, and small portable spot tamping machines are growing in popularity for section use on hard ballast lines, being especially effective around high speed turnouts and crossings. Apparently, new rail cannot be made to ride properly at 90 m.p.h. by any reasonable amount of spotting up, and surfacing should follow closely behind the relay.

There is still no substitute for good ties on any class of track, and roads which reduced standards slightly during depression years, soon found that tie conditions must be maintained at a higher level for fast than for moderate speeds, regardless of economic cycles. To distribute the effects of high speed impact better, some roads have decreased their usual tie spacing slightly, or increased their standard size from an eight to a nine inch top, and have adopted the 8 1/2-ft. length almost universally. Information from various sources indicates that some decrease in tie life on curves may be expected as a result of faster traffic, possibly as much as ten percent.

Subgrade stabilization is receiving attention wherever soft spots or mud squeezes are found under high speed track. Whether the cure is in the form of French drains, or tile or perforated pipe lines, piling or poles driven along the shoulder, or mats or slabs placed below the ballast section, the result is a smooth riding railroad, with a saving in labor that will soon refund the initial investment.

Replacement of open deck bridges with ballast decks has aided riding conditions by removing a source of troublesome maintenance at just so many bridge ends.

Maintenance force and expense.

The refinements outlined above as being necessary for present day operation, clearly mean increased maintenance. Last year a subcommittee of American Railway Engineering Association's Committee on Economics of Railway Labor, estimated that this increase would amount to between 10 and 30 per cent, or more, depending upon traffic and the physical characteristics of the property. Unfortunately, actual cost figures are still indeterminate, and we can only submit that this estimate is confirmed in replies to our questionnaire.

It is true that reduced traffic everywhere has lessened track punishment, but the studies of the A. R. E. A. committee show conclusively that the decline in man-hours worked has more than kept pace with the decline in traffic. This apparent discrepancy between higher maintenance standards and lower maintenance force is due, in part, to the improved design, strength and quality of track materials installed during recent years, in part to savings accruing from the widespread use of labor-saving equipment, and very largely to economies resulting from more efficient organization for, and methods of, performing track work.

As early as 1922 this Association heard it recommended that sections be extended and that maintenance work be handled by special gangs. The gang idea grew rapidly as the economies were recognized and as equipment was perfected, until now most railroads employ fully mechanized gangs to lay rail and to reballast. Only a little less common are similar gangs used to resurface on old ballast, to tighten bolts, to renew angle bars, and to spot and line track out-of-face. Several roads replace all ties with special gangs, and mechanical aids for this class of work are now being developed.

Consolidation of sections began on a large scale about 1930, and has continued intermittently up to the present time. We now find, on a representative mileage of well maintained, high speed railroad, that line sections average from 9 to 14 miles of heavy duty single track, or from 5 to 8 route miles of heavy duty double track. No general increase in the average number of laborers employed per section is apparent since 1930.

Handling the heavy maintenance tasks with special gangs has relieved the section force of practically all of the out-of-face work that was formerly its province, thus enabling it to spend as much as 90 per cent of its time smoothing and lining track. This organization is perfectly suited to high speed operation, with its ever-present demands that small track irregularities be corrected promptly and before they become extensive.

Every phase of maintenance work must have careful, intensive supervision. To aid in overcoming the handicap of extended roadmaster's districts, a number of roads use the track patrolman or track supervisor plan, as described by the Committee on Organization here in 1935, which relieves the section foreman of all track patrol except in case of storm.

Frequent inspection necessary.

In spite of stronger track construction, it is generally believed that present day speeds call for frequent track and switch inspection. This is accomplished efficiently by the Track Supervisor, who makes a round trip over his territory of 50 to 75 miles three times per week on a light inspection motor car. His observations, coupled with advice from the roadmaster, insure that the spots most needing attention will be corrected expeditiously, and that only the necessary work will be done at each location. Roads using this system report improved riding conditions, with a better quality and output of work, and feel that the plan is economically sound.

With only a definite number of maintenance dollars available, it is inevitable that certain niceties of appearance will be given somewhat less attention. Hand shaping of ballast section, hand control of vegetation, hand ditching and bank-widening have largely disappeared, and this work is now virtually all done mechanically. Labor thus conserved has gone into the maintenance of line and surface.

Maintenance problems are not confined alone to high speed territory. On secondary lines, passenger speeds have increased from 40 or 45 miles per hour to 60 miles per hour and more, with freight trains keeping pace. Instead of light-weight trains and modern locomotives, the older motive power has been speeded up, and the effects on track are too well known to warrant repeating here.

Little rail has been relaid on such lines since 1930, and ballasting has been greatly curtailed. Welding and joint bar renewals, ditching, bank-widening, and kindred improvements, have been deferred from year to year. The tendency to restrict tie insertions was evident for a few seasons, but it was found that poor ties were responsible for so much wasted labor and improperly riding track, that such conditions have generally been corrected.

No definite improvement programs are noted in connection with the quickened schedules, except where a moderate expenditure to line and surface a few grossly underelevated curves would permit a decided increase in speed. String lining is in favor, for here also, lining by eye alone is not entirely satisfactory for present day speeds.

Sections have been lengthened to an average of between 10 and 18 miles of single track and up to 12 route miles of double track, with central location of headquarters an important consideration. Tie renewal gangs are favored because of their mobility. With the long sections and small force, almost no out-of-face smoothing is done, and it is impossible to get tangents lined except in the relatively short locations where track is being spotted. This results in line irregularities over long distances, which are conducive to rough track, and special lining gangs show worthwhile economies by correcting this source of increased maintenance.

Supervision and inspection.

Extended sections have also made the Track Supervisor plan more attractive in proportion to the time required for track inspection and care of line switch lamps, that is thus saved the section gang. With the speeds above mentioned, the frequency of track patrol thus obtained is considered desirable. Judicious supervision is more than ever necessary, to insure that all available labor is expended where it will accomplish the utmost in strengthening the track and in improving riding conditions.

Branch lines.

On branch lines the speed trend is sometimes reversed. Wherever possible, train schedules have been lengthened to relieve track punishment, and frequently are governed wholly by the ability to get over a subdivision within the basic day. The lightest available motive power, appropriate to the requirements, is being used, although the obsolescence of small engines and the stepping back of heavy power render this impracticable on many railroads. Diesel units and auto-rail cars are receiving consideration, where the tour of duty can be made extensive enough to justify the investment. Such measures deserve the most careful study because of their effect on reducing maintenance.

Improvements in track structure are confined to the demands of safety. Section lengths have increased all out of proportion to the decline in traffic and now average 20 to 30 miles, with a few reported 40 miles long. Stability of subgrade and weight of rail are the two features most likely to determine the possible length. Section headquarters are centrally situated and the daily working location is coordinated with the requirements for inspection, which may be on the basis of three times, twice, or even only once per week. On a few lines this inspection is handled by an assistant foreman or leading laborer with a small motor car, who also makes sundry light repairs.

Some tendency is noted toward modified out-of-face maintenance. Ties are allowed to go a little longer and are then renewed by a special gang, which also spots and lines the track with the expectation that it will not be touched until the second season. The track may become somewhat rough, but not seriously so if tie conditions are reasonably good, and a little picking up by the section force will usually keep the line in shape for the speed and traffic carried. Heavy rail laid and rail anchors placed prior to 1930, and the almost universal application of tie plates during the last decade, are items which have reduced the branch line maintenance burden.

Conclusions.

Owing to the wide variety of local conditions, conclusions applicable to all railroads cannot be drawn. Certain generalities, may however, be permitted :

— Much can be done to relieve track abuse by proper scheduling and the observance of speed limits. Track irregularities are exaggerated by high speed, and smooth riding at these high speeds can only be obtained by greater refinements in maintaining the line and surface.

Special gangs for the heavier tasks and section gangs for the prompt correction of rough spots and for general policing, form an organization well suited to present requirements.

High speed has not called for any radical departure from established maintenance practices, but has merely intensified certain long-standing problems. Much has been learned in the last three years, and today's traffic is continually providing the stimulus for further development in every phase of track work, so that if the future should demand still more speed, maintenance men will be ready with the solution.

[625 .253 (.73)]

2. — Fluorescent lighting for cars on the New York Central Railroad.

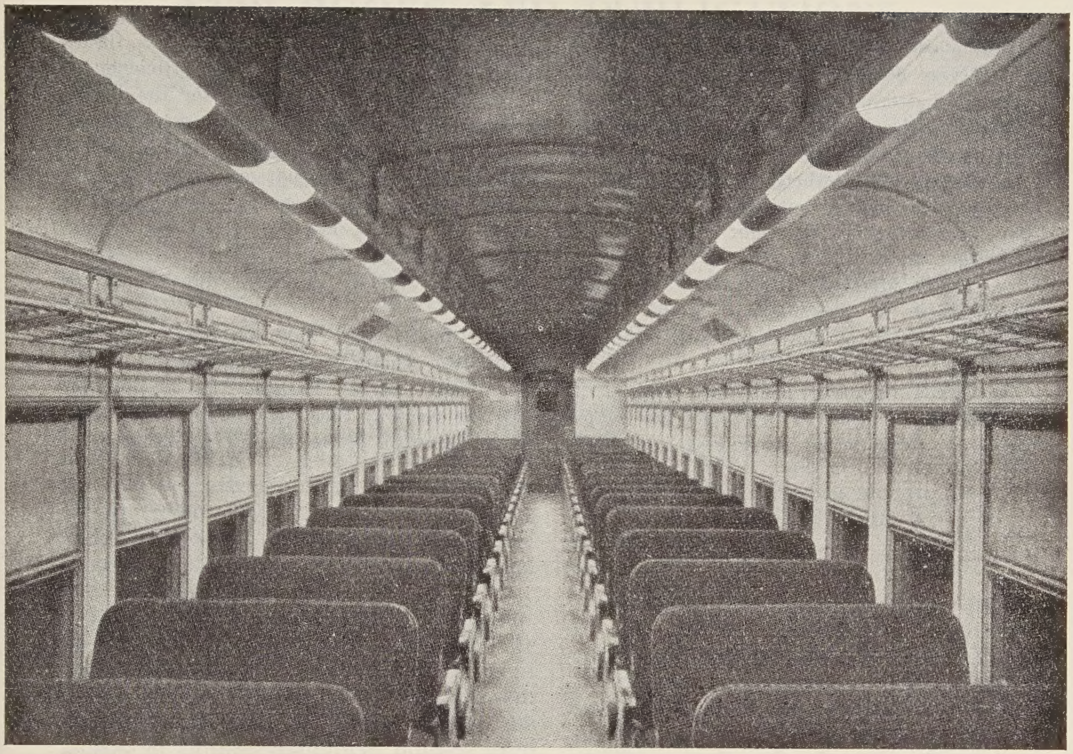
(*Railway Age.*)

Fluorescent lighting units, a newly developed product in the lighting field, have been applied experimentally to coach lighting by the New York Central Railroad. An installation has been made in a standard coach, the only change made to the car being the new lighting system. The power supply system remains a 2-kw. generator with 300 amp.-hr., 16-cell, lead storage battery.

This experimental installation was made to determine the ability of these lamps to withstand conditions of railway coach lighting service, the suitability of the inverting equipment required to produce the necessary alternating current power, and to determine the possibility of operating this equipment from the standard generator and battery used in coach lighting service.

The outstanding feature of the installation is the securing of approximately four times the illumination with only a small increase in the wattage input to the system. This result has been made possible chiefly by the characterstics of these fluorescent lamps. One of these lamps with a 16.5-watt overall input delivers considerably more light than the 25-watt incandescent lamps which they replace. The 25-watt lamps were spaced one over every other seat whereas the low wattage required by these new lamps permitted the spacing to be halved and a lamp located over every seat. Some increase in illumination is also secured because of the use of metal reflectors over the new lamps instead of glass which reduces the amount of light transmitted upward to the ceiling.

The lamps are tubular in form and contain mercury vapor. An electric arc through this vapor develops ultraviolet light but produces very little visible light. By coating the inside of the tube with certain materials, it is possible to change the wave length of the light from the invisible to the visible portion of the spectrum, this phenomenon being known as fluorescence. Lamps producing light of different colors at varying efficiences can be secured by selecting various coatings. The lamps used in this test installation produce a white light at an efficiency of 30 lumens per watt. An efficiency as high as 60 lumens per watt is possible when a fluorescent material giving a green light is used, but light of this color might not be acceptable for general lighting purposes.



General lighting in the car is supplied by forty 15-watt tubular (white) fluorescent lamps, mounted in continuous fixtures along the deck sill moldings with the lamps about 7 ft. 6 in. above the floor, one over each seat. The seats are spaced on 36-in. centers. The lamps are 18-in. long by 1 1/2 in. in diameter. The fixtures have a semi-cylindrical Alzak reflector at the top and plastic louvers at the bottom which prevent seeing the bare lamps when looking down the car. The power consumption of the lamp proper is 15 watts. An additional 1 1/2 watts is consumed in a ballast reactor, which is required to stabilize the operation of the lamp. These reactors are mounted in closed sections of the fixtures between the lamps.

In addition to the fluorescent lamps, there is one 25-watt, 32 volt incandescent lamp over each of the two end seats, one in each toilet and two in each vestibule. Thus the power consumption for lights is 660 watts for the fluorescent units and 200 watts for the incandescents, making a total of 860 watts. When the car is running the average illumination is 10.1 foot-candles on the reading plane at the window seats, and 11.7 on the aisle seats, with a general average of 10.9. The lamps in the vestibules are mounted in twin condenser lens fixtures, which provide an intensity of 4.3 foot-candles on the platform at the center of the vestibule, 2.2 at the edge of the top step, 1.6 at the edge of the other steps and the light extends well out from the car when the vestibule side doors are open.

The fluorescent lamps require alternating current for their operation and this is obtained by substituting a rotary inverter (motor-driven commutator) for the customary lamp regulator. The inverter takes 32-volt direct-current power from the battery and generator and delivers 60-cycle, 115-volt energy to the lamps. The alternating-current voltage is proportional to the direct-current voltage and the latter varies from battery voltage at standing to generator voltage when the car is running. This does not make a noticeable difference in light intensity, since the light output of the fluorescent lamps varies only in the ratio of 0.8 : 1 as contrasted with the 3 : 1 ratio characteristic of incandescent lamps. The maximum voltage on the fluorescent lamps is about 130.

The lamps regulator commonly used in a passenger car is required to protect the lamps from over voltage while the generator is running and battery charging. The efficiency of the inverter is about 75 per cent, a figure which corresponds closely to the efficiency of a lamp regulator. Protection for the incandescent lamps in the car is secured by a fixed resistance which is inserted in the incandescent lamp circuit automatically when the generator begins to charge the battery. The fluorescent lamps are controlled by circuit breakers and are connected in two circuits so that either all or alternate lights may be used.

The installation was developed by the Equipment Engineering Department of the New York Central Railroad in conjunction with the General Electric Company and with the co-operation of the fixture manufacturers.

NEW BOOKS AND PUBLICATIONS.

[621. 33 (02]

SACHS (Dr. techn. Karl). — Die **ortsfesten Anlagen elektrischer Bahnen** (*The Fixed Equipment of Electric Railways*). — One volume, quarto (8 × 11 inches), of 321 pages, with 430 figures in the text and 8 inset plates. — 1938, Orell Füssli, publishers, Zurich and Leipzig. (Price : 48 Swiss francs or 29 RM.)

This work, the author of which is engineer to the Brown Boveri Company and a professor at the Higher Technical Federal School at Zurich, deals with the fixed equipment of electric railways and forms a complementary volume to the important treatise on main line electric locomotives (1) published by the author in 1928, so completing the task he had set himself, that of treating the whole range of questions involved in the field of electric traction in a manner equally suited both to the student and the practical man.

In a short introduction the Author first of all investigates the effect on the fixed equipment of the kind of current adopted. Dealing with the equipment itself, he discusses in succession the source of supply, the power houses, high tension feeders, sub-stations and the contact systems.

The book thus consists essentially of four chapters, the first three of which did not stand in need of such full development as the fourth, as they are concerned with equipment not differing fundamentally from that employed for the production, transmission and distribution of electricity for purposes other than traction. All that was needed, therefore, was to bring out the particular features or typical installations associated with the working of electric railways.

Chapter I deals with power stations, discussing the question of their capacity in relation to the running resistance of the trains and the traffic to be handled. The principles involved in establishing steam and hydro-electric power stations are then discussed, with single and three-phase generators, and transformers.

The second chapter describes the erection of high-tension feeder lines and has three sections dealing with 50 to 66 kV., 80 to 110 kV., and above 110 kV. lines.

Substations are dealt with in Chapter III, the author discussing the importance of sub-stations and their location to meet a given density of traffic and a certain permissible voltage drop. The sub-stations for various kinds of current are then dealt with, first for direct current, viz : those with motor-generator sets, rotary converters and mercury-arc rectifiers; then for single-phase current, sub-divided into sub-stations receiving their supply as single-phase, and those receiving it as three-phase current; finally sub-stations for three-phase traction are described.

The most important part of the book deals with the design and installation of contact systems. It opens with a discussion of the subject from an electrical point of view, the calculations for voltage drop, both for direct and alternating current; mechanical considerations are next dealt with, with calculations and constructional details, first of all for overhead wire equipment and then for the third-rail system.

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(1) « Elektrische Vollbahnlokomotiven » — (Electric Main Line Locomotives), — Julius Springer, publisher, Berlin, 1928.

The work concludes with notes on the signalling of electric railways, fixed equipment for train pre-heating and lighting in the special case of single-phase traction at a frequency of 16-2/3 cycles.

The book has been very carefully edited; all questions are treated in the most methodical manner, while numerous diagrams and figures spread throughout the text assist the reader to understand it. Altogether it forms an excellent text and reference book which cannot fail to be welcomed favourably by all those concerned with that important present-day question, electric traction.

[**621. 138.5 (.54)**]

BAILEY (L. G.), M. I. L. E., Works Manager, Khargpur. — Description of the **method of locomotive repair** as carried out in the Khargpur Workshops of the Bengal Nagpur Railway. — A booklet (10 × 6 1/4 inches) of 21 pages, with 10 photographs and 9 tables appended. — 1938, Calcutta. Printed for the Railway Board at the East Indian Railway Press. Copies obtainable from the Manager of publications, Delhi. (Price : As. 12, or 1 sh. 3 d.)

Mr. BAILEY, Works Manager at Khargpur, Bengal Nagpur Railway, describes in this booklet the new organisation set up for repairing steam locomotives on the belt system, introduced in the workshops about 1928.

The erecting shop, built in 1904, contained originally three tracks with pits, arranged longitudinally. Each could take 21 locomotives for heavy overhauls. At present the principal belt occupies no more than the centre track, able to accommodate 20 locomotives. This belt comprises, inside the shop, 13 stages, 12 of one day each, and an 8-day stage, the latter being allocated to important repairs to frames and cylinders; 22 working days are taken for a complete overhaul, the last two being devoted to tests and final adjustments.

The two lateral tracks have only been retained for a short length; one serves for special repairs, the other contains equipment for adjusting valve gears, an operation which is intercalated in the eleventh stage of the belt.

Repairs to valve chests, pistons, rods, motion and brake gear are effected in subsidiady belts arranged laterally to the main one. The description includes diagrams giving a very clear idea of the arrangement of the principal belt and the different subsidiary ones, with indications of the stages, the location of the machine tools, fitters' benches, and the arrangements for effecting the progressive movement of the parts under repair.

The Khargpur works have thus been re-organised according to the most up-to-date principles and the results obtained have been such as are normally achieved with the belt system, namely, an important reduction in the number of hands necessary, a considerable reduction in repair time, brought down from 63 working days before 1928 to 22, and a better use of shop space. The author quotes a characteristic figure concerning the number of locomotives held out of service in the workshops, which was 128 before 1928, and is now only 28, representing an appreciable improvement in locomotive utilisation.